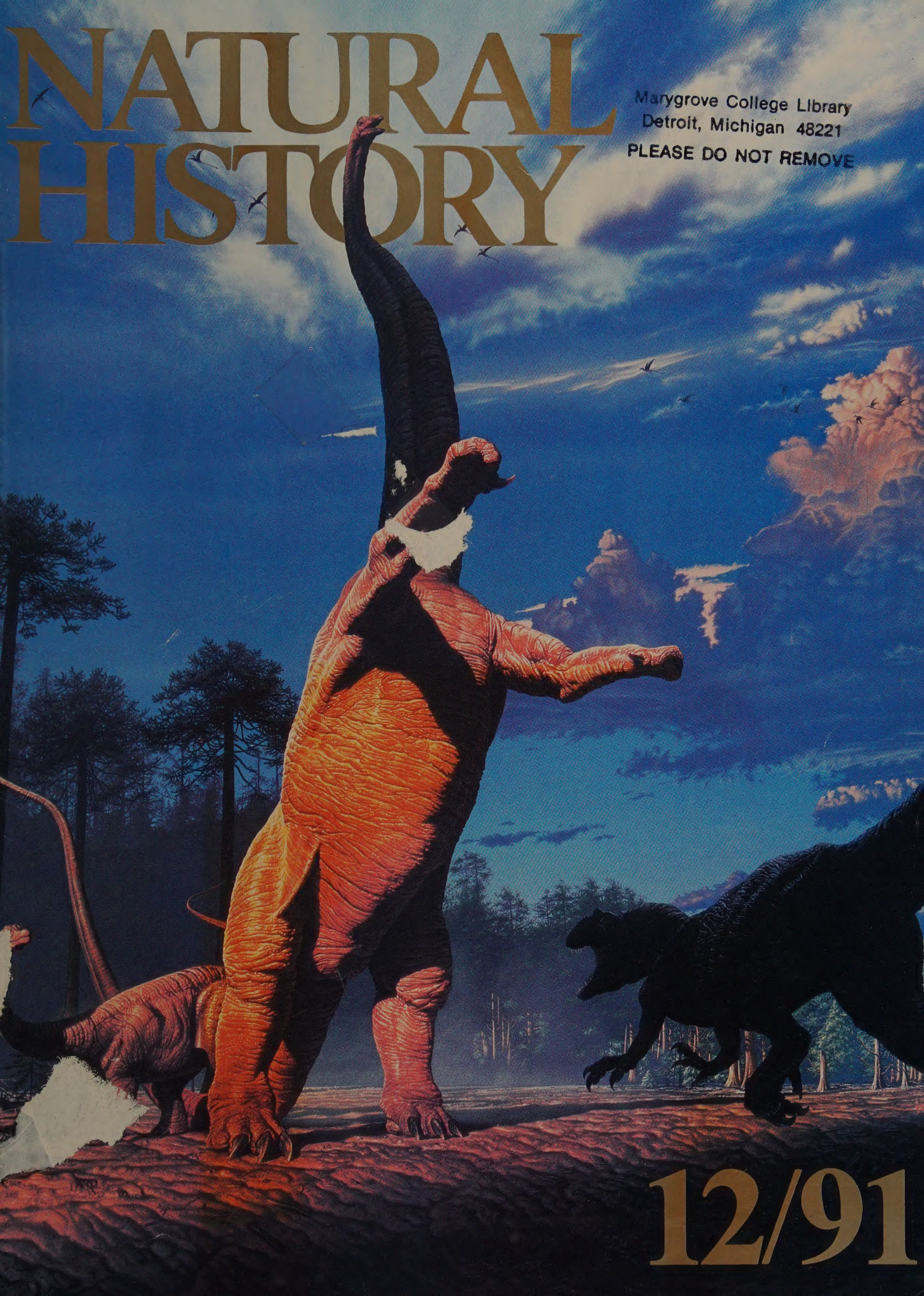


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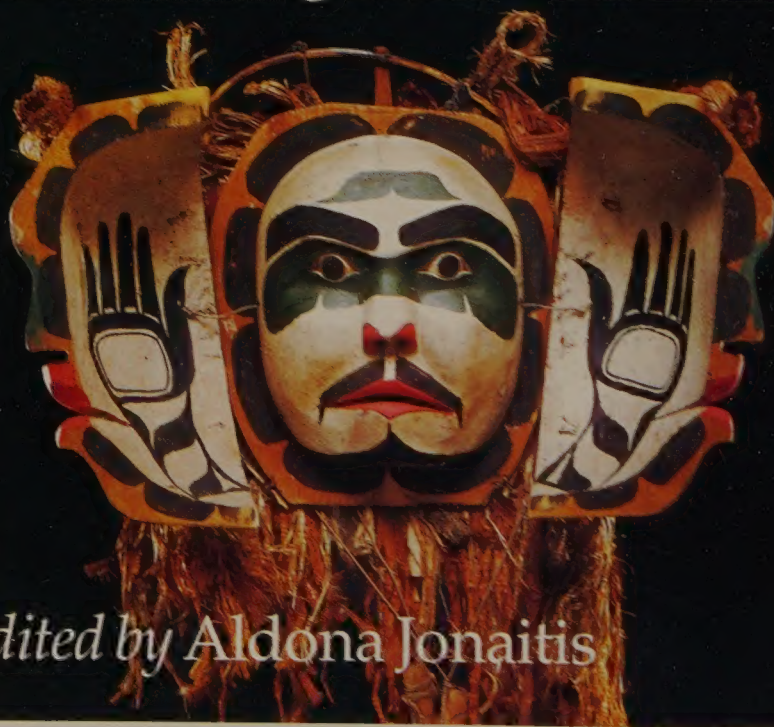
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COVER: A Barosaurus defends her young from a predatory Allosaurus while a flock of pterosaurs flies overhead. Stories about these dinosaurs and a new fossil exhibition at the American Museum of Natural History begin on page 28.
Painting by John Gurche © 1991.

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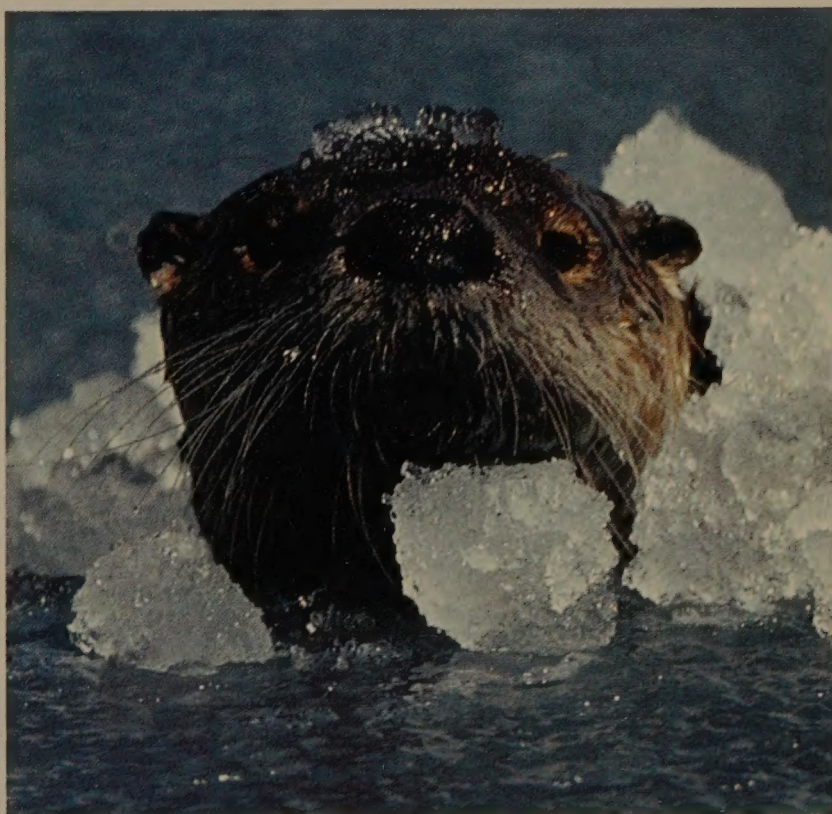
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NATURE'S INFINITE BOOK

Pearl Harbor and the Emperor's Physiologists

Our ability to feel comfortable in hot climates depends on where we spent the first few years of childhood

by Jared Diamond

Japan's attack on Pearl Harbor fifty years ago illustrates dramatically, in the political sphere, how conditions during a brief but critical time span can launch irreversible developments. Two hours of bombing forged an American determination for war that several previous years of distant events had not produced. If our fleet had been placed on top alert as soon as our radar and the destroyer SS *Ward* had detected the oncoming attack, our battleships might have suffered much less damage. In that case they might have thwarted Japan's invasion of the Philippines and Indonesia, and the Pacific war would have ended quickly. If, on the other hand, the Japanese attackers had destroyed our aircraft carriers, docks, and fuel tanks, along with our battleships, we would have been unable to defend New Guinea or Guadalcanal. Japan's position might then have proved impregnable, despite our much greater industrial output. Thus, the Pearl Harbor attack virtually insured that there would be a Pacific war, that it would be a long one, and that Japan would ultimately lose it.

Biologists, too, have come to appreciate that exposure to certain stimuli during a sensitive time span may create irreversible effects. Critical-period programming, as it is termed in biology, forms an intriguing middle ground between two better-known extremes: irreversible genetic programming of our bodies and repeated, reversible programming throughout life. This month's fiftieth anniversary of the attack on Pearl Harbor provides a good occasion for consideration of critical-period pro-

gramming, because Imperial Japan's physiologists contributed decisive insights to that field of science during the course of Japan's overseas expansion leading to Pearl Harbor.

The example that I'll discuss involves a phenomenon familiar to all of us from experience: our individually varying tolerance of heat and cold. If you observe your friends on a cold winter day, you'll notice that some are shivering, while others, similarly dressed, appear comfortable. Such differences between husband and wife are notorious for provoking "battles of the bedroom" over how hot to set the thermostat or whether to open the windows. In summer you can see how people differ in their tolerance of heat. Among a group of your friends, some will be wilting, while others are comfortable; some will be drenched in sweat, while others are scarcely sweating at all.

These individual differences began to impress Japanese physiologists in the early twentieth century. Until Commodore Perry "opened" Japan in 1853, the Japanese, a remarkably homogeneous people, were confined to the modest range of climate in their home islands. With Japan's acquisition of tropical Taiwan (1895), the tropical Marianas and Caroline Islands (1914), and cold Manchuria (from 1905 onward), the Japanese became exposed to a much wider range of climates and peoples. Japanese civilian study of climatic physiology was pioneered by Yas Kuno, a great physiologist who did research at the Medical College of Manchuria from 1911 to 1935 and then

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worked in Japan itself. Japanese opportunities and motivation for study peaked after Pearl Harbor; as millions of Japanese went overseas to hot or cold battlegrounds, Japanese military research groups did extensive studies of soldiers, prisoners, and civilians. While this wartime burst of research collapsed cataclysmically within a few years, Japan's academic tradition of climatic physiology resumed after the war. Some of the resultant knowledge helps us to understand racial differences in human physiology, but much of it proves applicable to all humans; it just happens that the subjects being studied were predominantly Japanese.

Especially illuminating was the research of Kuno and his students and colleagues on how our ability to sweat adapts to hot climates. As background, recall that we humans, perhaps because of our sparse body hair, are much better endowed with sweat glands than are most other mammals. These glands serve several functions. Glands on our palms and soles keep those surfaces moist, thereby improving our grip and our sense of touch. Glands in our armpits broadcast odors as sexual signals after we reach puberty. Many mammals broadcast such odors from the area around the genitalia and anus, which are positioned at the same height above the ground as a quadruped's nose. One may speculate that when human upright posture raised our nose high above our genitals, secretion of advertising odors shifted to the armpits so as to be close to nose height. Japanese physiologists reported that the capacity for armpit sweating correlates racially with the profusion of armpit hair: ample in Russians, reduced in Japanese, and least in Chinese.

Apart from the glands in our palms, soles, and armpits, sweat glands distributed over the rest of our body serve to keep us cool by the same principle employed in refrigerators: evaporation of a liquid (Freon in refrigerators, water in our sweat glands) carries away heat. For example, evaporation of a pint of sweat lowers the body temperature of a 140-pound person by about 10° F. In the course of an eight-hour work shift, Japanese factory workers in the summer lost up to twenty-four pounds by sweating, while soldiers doing heavy work in the tropics sweated at a rate of up to one gallon per hour. They thereby maintained a constant body temperature, despite the heat influx from the surrounding air plus the heat produced by their own hard-working bodies.

When I visited Finland many years ago, the human body's capacity to cool itself by sweating was illustrated for me by a vivid demonstration that Finns loved to inflict

on visitors. I was taken into a sauna, which is really nothing more than a heated, dry room with a bucket of water and a ladle on the floor. My friends raised the temperature to 260° F (nearly 50° F above boiling). They professed to love those conditions—I found them bearable, though uncomfortable—but we all sweated profusely and thereby maintained body temperature and survived. To prove that the thermometer wasn't lying, my friends cracked an egg on the floor. The egg quickly cooked, because it lacked sweat glands. When more people entered the sauna and it began to feel crowded, someone shouted, "*Enemmän löyly!*" (more steam) and threw a ladleful of water onto the floor. The room quickly became humid, preventing our sweat from evaporating. As our temperatures rose, the less hardy souls (including me) staggered out of the room, leaving the toughest fanatics to enjoy the sauna by themselves.

If you leave a cold climate for a tropical vacation, you can satisfy yourself that your capacity to sweat adapts to the new conditions over the course of a few days or weeks. For a given test exposure to heat, people who have acclimatized themselves to the heat produce more sweat and begin to sweat sooner than those who have not had that time. As one example, experienced workers in hot mines produce about three times as much sweat per work shift as do beginning miners. The earlier onset of sweating is due to greater excitability of the brain's nerve centers controlling sweating, while the higher sweat rate involves adaptation by our sweat glands themselves. Still another physiological adaptation to hot weather is vasodilatation, or dilated blood vessels, which increases blood flow through the skin and permits us to radiate more heat by that route. All these adaptations reverse themselves shortly after a return from a warm to a cold climate.

In addition to these reversible responses, Japanese physiologists also noticed seemingly fixed differences between tropical natives and temperate-zone visitors to the tropics. You too can convince yourself of those differences by comparing yourself with the natives, even at the end of a long vacation that you've spent in the tropics. In moderately hot weather natives remain dry, while we visitors sweat profusely, so that our skin and clothes are constantly drenched. During my fieldwork in hot Indonesia, I am always surprised when my Indonesian colleagues remain comfortable in their long trousers and shirts, while I'm shirtless and in shorts but still dripping wet. A few years before Pearl Harbor, Japanese physiologists

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quantified this familiar experience by comparing responses of Philippine natives and Japanese settlers in the Philippines. Subjects from each group were tested with one leg immersed in a tub of hot water. When the water temperature was 114° F, the sweat responses of Japanese and native Philippine subjects were similar. But when the water temperature was lowered to between 110° F and 112° F, Philippine subjects showed no sweat reflex, although the Japanese subjects sweated as profusely as before.

In effect, tropical natives are more tolerant of heat than are some temperate-zone visitors and require a stronger stimulus before they need to begin sweating. This may sound paradoxical, since I just explained that newly arrived visitors also require a stronger stimulus than do heat-acclimatized visitors. The resolution of this paradox probably involves other adaptations of tropical natives for reducing heat influx or tolerating heat loads and thereby not having to live drenched in sweat.

Measurement of sweat's salt concentration revealed a further advantage of tropical natives. While all the cooling power of sweat arises from its water content, sweat also has to contain salt, because our sweat glands have no mechanism for secreting water itself. Instead, in the first stage of sweating, the glands secrete salt, which pulls water along by osmosis; in the second stage, the glands resorb some of the secreted salt. Salt resorption is much more complete in Taiwanese, Thais, and Filipinos than in Japanese—perhaps because tropical natives produce more of the adrenal hormone aldosterone, which regulates salt resorption. That adaptation is a big plus for them because it minimizes the risk of collapsing from salt loss during profuse sweating.

While tropical natives are harder to provoke into sweating, they can sweat more profusely when conditions demand it. It turns out that this is simply because they have a greater number of functional sweat glands. To count the number of glands, cover a small area of your skin with colored oil, then provoke yourself into vigorous sweating (for example, by drinking a big cup of hot tea). The mouth of the pore where each gland opens onto the skin's surface can then be located under a microscope by the gleaming white sweat droplet pushed up under the oil. Mapping out your functional glands in this way, you'll find yourself able to spot the same glands at the same location from day to day. Extrapolating from a small area of skin to the whole body surface, Japanese physiologists calculated the following average

values for total number of functional sweat glands per person: 1.4 million for the Ainu people of cold Hokkaido Island; 1.9 million for Russians; 2.1 million for Japanese; but 2.4 to 2.8 million for the peoples of tropical Thailand, Taiwan, and the Philippines. Hence, a major reason that tropical natives can remain comfortable under hot conditions is that they have more functional sweat glands and can cool down faster.

It's tempting to assume that the differences in sweat gland numbers between Japanese and tropical peoples are genetic and arose through natural selection. One can easily imagine how, in the tropics, people born with the most sweat glands would be less prone to heat stroke, would feel less wiped-out much of the time, and so would have more energy to rear babies and pass on their genes. In accord with this view of genetic determination of sweat gland numbers, Japanese immigrants who have lived in the tropics as adults for decades still have fewer functional sweat glands than do tropical natives.

But a beautiful set of observations by Japanese physiologists exploded this appealing interpretation. Especially during the years between the world wars, there was much flow of emigrants and re-immigrants between the Japanese homeland and the Asian and Pacific tropics. Japanese settlers emigrated to the tropics at various ages, gave birth to children in the tropics, and some of those children returned to Japan at various ages. The physiologists found that the number of functional sweat glands in tropical-born Japanese rivaled the high numbers in tropical natives! Conversely, Japan-born Japanese who emigrated to the tropics as children and remained there for decades retained the low sweat gland count of life-long residents of Japan. Evidently, our number of functional sweat glands is not immutably fixed by our genes but is instead fixed by the climatic conditions that we experience very early in life.

The explanation for this remarkable result emerged from heroic studies carried out by the physiologists Korehiro Ogata and Aikoh Kawahata in the years just before Pearl Harbor. Ogata sat for an hour in a hot chamber at 113° F until his sweat was flowing profusely onto the floor. He then used a microscope to measure the number of functional sweat glands in a small area of his skin (by counting the gleaming sweat droplets under the colored oil). Finally, he cut off that piece of his skin, fixed it for histological examination, and counted up the actual number of sweat glands. He found that the actual

number of glands exceeded the number of functional ones producing sweat droplets. That is, many of his sweat glands never saw action, even though they were identical in appearance to the functional glands.

Other studies had shown that sweat glands begin to form in the human fetus at about the fourth or fifth month of gestation. At about seven months of gestation, the glands can already be stimulated into secreting by injecting a suitable drug. However, infants cannot yet sweat in response to heat (as opposed to drug injections) on the day of their birth. Instead, it takes from two to eighteen days for most babies to start to develop a sweat reflex. Kawahata therefore exposed Japanese babies and adults of various ages to heat, counted the number of functional sweat glands in 60 to 100 areas of skin distributed over the whole body, and added up each person's total number of functional sweat glands. That number gradually increased up to the age of two or three years and then remained constant through adulthood.

Putting these and other studies together, we arrive at the following formulation. All of us are born with roughly the same actual number of sweat glands, none of which respond to heat at birth. That response depends on nerve reflexes, through which a center in the brain receives sensory information about heat and then uses that information to send out signals on motor nerves controlling the sweat glands. Those reflex arcs become functional through use resulting from experience of hot conditions—but only during the first few years of life. The hotter the conditions under which we grow up, the greater the number of our sweat glands that get programmed to function. By age two or three, the programming is as complete as it ever will be. If we grow up in a hot climate, most of our glands become activated, and for the rest of our lives we'll be able to stay comfortable in hot weather by sweating profusely. If we grow up in a cold climate, our body soon decides that that's what it will be like until we die, and barely more than half our glands become programmed.

In the jargon of modern biology, sweat gland function is fixed irreversibly by critical-period programming—that is, by conditions prevailing at a certain critical age, usually early in life. Well-known examples of this phenomenon abound in the field of animal behavior. For example, the great ethologist Konrad Lorenz got goslings to follow him around as if he were their mother, because goslings are born with a mental program telling them to follow the large moving object that they see within a

short critical period after they hatch. Normally that object is their mother, but goslings can become programmed to follow Konrad Lorenz or another large moving object if it appears first.

Critical-period programming has been identified for many other human traits besides sweat gland function. Neurophysiological examples include our ability to see and speak. People born with a mechanical impediment to sight that can be corrected surgically cannot learn to interpret the normal range of visual information if the correction is postponed until after a certain point in childhood. Again, people deprived of the opportunity to learn language in childhood—like the famous wolf boy of Aveyron—do not master language if exposed to it late. Those of us who do learn to speak generally acquire much better pronunciation in a language that we learn as young children than in a language that we first study as adults. Evidently, our neural pathways for handling visual or linguistic information become programmed early. A corresponding behavioral example is the molding of our sexual preference: as children we form unconscious search images, modeled on the people we then see around us, that will influence which potential sex partners are most attractive to us as adults.

Thus, our bodies respond to our environment or life style with several possible levels of flexibility. Most flexible are body features that we can change any number of times as adults—such as our muscle strength, which waxes and wanes with exercise. Least flexible are genetically fixed attributes, such as eye color, which we not only cannot change ourselves but also pass on unchanged to our offspring. For such inherited traits, a rut from which we can never swerve is selected for us at the moment of conception.

Critical-period programming offers an intermediate level of flexibility. We end up in a rut, yet that rut isn't selected for us until after conception. Hence our rut can be matched to current conditions around us—unlike the case for an inherited trait, which is matched only to average conditions faced by our ancestors over many generations of natural selection. If we move later in life to a different environment, we ourselves can't change. But at least our children will be as well adapted—in pronunciation, sweating ability, and some other respects—as children whose ancestors have resided there for many generations.

Jared Diamond studies physiology and evolutionary biology at UCLA Medical School and works in the hot tropics.

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The Smoking Gun of Eugenics

Should we—can we—take a kindly view toward a hero's faults?

by Stephen Jay Gould

Do Baptist preachers cause public drunkenness? I raise this unlikely inquiry because an old and famous tabulation clearly shows a strong positive correlation between the number of preachers and the frequency of arrests for inebriation during the second half of the nineteenth century in America.

You don't need a Ph.D. in logic to spot the fallacy in my first sentence. Correlation is not causality. The undeniable association of preachers and drunks might mean that hellfire inspires imbibing, but it could also, and more reasonably, suggest that a rise in public drinking promotes the hiring of more preachers. As another possibility—almost surely correct in this particular case—preaching and drinking may have no causal relationship, and their simultaneous increase may only reflect a common link to a third, truly determining factor. The steady rise of the American population during the late nineteenth century promoted an increase in thousands of phenomena linked to total numbers but otherwise unrelated—arrests for drinking and hiring of clergy, for example. This tale has long served as the standard textbook example for illustrating the difference between correlation and causality.

But good principles can also be used to buttress bad arguments. I have often stated in this forum that only great thinkers are allowed to fail greatly—meaning that their errors, although large in scope and import, are invariably rich and instructive rather than petty and merely embarrassing. This essay treats the two greatest errors of the twentieth-century patron saint in my profession of evolutionary biology.

Most general readers may not know the name of Sir Ronald Aylmer Fisher (1890–1962), for he wrote nothing for

nonprofessional consumption, and the highly mathematical character of his technical work bars access to many full-time naturalists as well. But no scientist is more important as a founder of modern evolutionary theory, particularly for his successful integration of Mendelian genetics with Darwinian natural selection. Fisher's 1930 book, *The Genetical Theory of Natural Selection*, is the keystone for the architecture of modern Darwinism. Fisher built with mathematics, and most biologists will say (although I would disagree in important respects) that the field he founded—population genetics—is the centerpiece of evolutionary theory. Fisher was also one of the world's most distinguished statisticians; he invented a technique called the analysis of variance—now about as central to statistics as the alphabet is to orthography. In short, Fisher is the Babe Ruth of statistics and evolutionary theory.

But the Babe also struck out a lot, and Fisher made some major-league errors. Most of my colleagues know about the two key mistakes that I will analyze in this essay, but they just aren't discussed in polite, professional company. One is dismissed as an inconsequential foible of Fisher's old age, while the other is bypassed in silence, although it occupies more than one-third of Fisher's most important 1930 book.

During the last half dozen years of his life, Fisher spent considerable time and several publications trying to debunk the idea that smoking causes lung cancer. Sir Ronald, who enjoyed his pipe, did not deny that a real correlation between smoking and lung cancer had been found. But following the textbook paradigm of preachers and drunkards, he disputed the claim that causation ran directly from

smoke to cancer. He presented the two other logical possibilities, just as the texts always do for Baptists and boozers. First, cancer might cause smoking rather than vice versa. This inherently implausible version seems hard to defend, even as an abstract argument for the sake of conjecture, but Fisher found a way.

As a smoker, Fisher extolled the soothing effects of tobacco. He also recognized that cancers take years to develop and that future sufferers live for several years in a "precancerous state." He supposed that lungs might be chemically irritated during this precancerous phase, and that people so afflicted might increase smoking for psychological relief from an unrecognized physical ailment. A bit strained, but not illogical. Fisher wrote in 1958:

Is it possible, then, that lung cancer—that is to say the pre-cancerous condition which must exist and is known to exist for years in those who are going to show overt lung cancer—is one of the causes of smoking cigarettes? I don't think it can be excluded. . . . The pre-cancerous condition is one involving a certain amount of slight chronic inflammation. . . . A slight cause of irritation—a slight disappointment, an unexpected delay, some sort of mild rebuff, a frustration—is commonly accompanied by pulling out a cigarette, and getting a little compensation for life's minor ills in that way. And so anyone suffering from chronic inflammation in part of the body (something that does not give rise to conscious pain) is not unlikely to be associated with smoking more frequently, or smoking rather than not smoking. . . . To take the poor chap's cigarettes away from him would be rather like taking away his white stick from a blind man.

But Fisher recognized that the second alternative explanation for the correlation of smoking and lung cancer—the association of both, independently, with a truly

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causal third factor—held much greater plausibility and promise. And Fisher had no doubt about the most likely common factor—genetic predisposition. He wrote: “For my part, I think it is more likely that a common cause supplies the explanation. . . . The obvious common cause to think of is the genotype.” In other words, genes that make people more susceptible to lung cancer might also lead to behaviors and personalities that encourage smoking. Again, the argument is undeniably logical; genes may have multiple effects, both physical and behavioral. To choose an obvious example, several forms of mental retardation have no causal relationship with correlated physical features: short stature does not produce retardation (or vice versa) in people with Down’s syndrome.

With the hindsight of an additional twenty-five years, we may say conclusively that Fisher was wrong, and tragically so. Smoking is a direct and potent cause of lung cancer—the reason for hundreds of thousands of premature deaths in America each year. Yet I cannot fault Fisher on the logic of his argument: correlation is not causality, and the bare fact of correlation does permit the three causal scenarios that Fisher detailed. If Fisher had presented his objections to the indictment of smoking only as a cautionary claim in the absence of conclusive data, then we could not blame him today. (One cannot always be right in our complex

world; no dishonor attends an incorrect choice among plausible outcomes drawn from a properly constructed argument.) But in Fisher’s case, we have reason to question his motives and his objectivity—and some judgment for his incorrect conclusion may therefore be exacted.

Fisher did present his case with the conventional rhetoric of science. He claimed to be both objective in his weighing of evidence and agnostic about the outcome. He maintained that he had raised the issue only in a proper scientific spirit of caution and love of truth. Fisher made three explicit arguments for special and scrupulous care in treating such a socially charged issue, a potential matter of life and death.

1. Millions of people enjoy smoking. We dare not poison the source of their pleasure without conclusive evidence. Fisher pleaded for the psychic health of ordinary smokers in the elitist language of an Oxbridge don (Fisher was the Balfour Professor of Genetics at Cambridge and, at the end of his career, president of Gonville and Caius College):

After all, a large number of the smokers of the world are not very clever, perhaps not very strong-minded. The habit is an insidious one, difficult to break, and consequently in many, many cases there would be implanted what a psychologist might recognize as a grave conflict. . . . Before one interferes with the peace of mind and habits of others, it seems to me that the

scientific evidence—the exact weight of the evidence free from emotion—should be rather carefully examined.

Writing more forcefully in a letter to the *British Medical Journal* (July 6, 1957), Fisher compared the claims of antismoking forces with the classic case of hysteria mongering: “Surely the ‘yellow peril’ of modern times is not the mild and soothing weed but the organized creation of states of frantic alarm.”

2. If we make a strident claim for smoking as a cause of cancer, and if we then turn out to be wrong, the entire enterprise of statistics will be discredited. In a further letter to the *British Medical Journal* (August 3, 1957), Fisher pleaded for caution as a protection for science:

Statistics has gained a place of modest usefulness in medical research. It can deserve and retain this only by complete impartiality. . . . I do not relish the prospect of this science being now discredited by a catastrophic and conspicuous howler.

3. In situations of uncertainty, we need more research above all. Premature conclusions stifle further investigation. In yet another letter, this time to *Nature*, Britain’s leading journal for professional scientists, Fisher wrote (August 30, 1958): “Considerable propaganda is now being developed to convince the public that cigarette smoking is dangerous.” In his letter of August 1957, Fisher had already specified the perils of such a campaign: “Excessive confidence that the solution has already been found is the main obstacle in the way of more penetrating research.”

Fisher’s last point backfired strongly on him—an ironic illustration of its power and truth. Fisher supported his suspicion that smoking does not cause cancer with two poorly documented sets of data—a curious claim that people who inhale show less cancer, for the same amount of smoking, than those who do not inhale; and a puzzling contention that lung cancer is increasing faster in men than in women, whereas smoking has risen more rapidly in women. The inhaling data were drawn from a very poorly constructed questionnaire. Most respondents may not even have known the meaning of the word *inhale* and may have checked “no” in simple confusion. Later information shows a strongly positive correlation of cancer with inhaling, when all other factors are held constant. As for men versus women, Fisher’s argument was sound, but the data were wrong. The ever-accelerating incidence of lung cancer in women now ranks among the strongest points of evidence for a causal connection.

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It was an unlikely alliance. But when five state governments, two wildlife conservation groups and one energy company came in with concern and came out with solutions, it seemed more inspired than unlikely, after all.

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Fisher in this sorry incident emerges not from the logic of his argument (which was sound, although his conclusion, based on inadequate data, was wrong) or from his proper words of caution, but from a clear inference that he did not live by his own stated strictures. Evidently, Fisher did not approach the issue of smoking and cancer with the open mind that he championed as so necessary for any good science. He maintained an obvious preference for denying that smoking causes cancer—even though he states, again and again, that the raw data of an admitted correlation offer no preference for any of the three potential interpretations. Two aspects of his writing give the game away. First, his language. Just consider the sample quoted above. He calls for argument “free from emotion” and for “complete impartiality.” Yet the claim that smoking might cause cancer is labeled as “propaganda,” probably a “catastrophic and conspicuous howler,” and a “frantic alarm” acting as the “‘yellow peril’ of modern times.”

Second, his treatment of limited data then available. Fisher accepted, virtually without question or criticism, the inadequate but exculpatory data, previously cited, on inhaling and incidence in men versus women—even though both sets would soon be discredited. Fisher then showcased some even more dubious data supposedly consonant with his favored view that both cancer and smoking arise independently from a common genetic predisposition. Two studies compared the smoking behaviors of identical and fraternal twin pairs. Smoking preferences were more often shared by identical than by fraternal twins. Since identicals form from one egg and therefore share the same genetic program, while fraternal develop from two eggs and are no closer genetically than any other pair of siblings, Fisher concluded that the greater similarity of identicals must indicate a strong genetic basis for smoking preferences.

But this inference is both potentially wrong and largely irrelevant to Fisher's

argument. First of all, the greater smoking similarity of identicals could, at most, indicate a genetic predisposition in attitudes toward the weed; such data say nothing at all about genetic bases for cancer or about correlation of the two potential predispositions. Moreover, Fisher's data do not even prove his basic assertion of genetic predisposition for smoking. Fisher's explanation does represent one potential interpretation of the data, but another clearly exists, and he hardly considers it. Identical twins look alike and are frequently raised to emphasize the eerie similarity; they are often dressed alike, learn to act as surrogates one for the other, and so on. Perhaps this greater similarity in raising leads to a stronger likelihood for similar smoking habits.

In any case, Fisher should have considered all these possibilities if he were truly pursuing this issue with an open mind. We must conclude, rather, that he entered the fray with a clear preference, even a mission—the debunking of smoking as a cause, and a championing of joint genetic predisposition as an alternative explanation. We must therefore probe deeper and ask why Fisher had such an overwhelming preference. Two factors stand out: one immediate and practical; the other, longstanding and theoretical.

The immediate reason is easy to state and hard to gainsay. In 1956, Fisher became the paid scientific consultant for the Tobacco Manufacturers' Standing Committee. Fisher took great umbrage at any implication that his objectivity might be compromised thereby, arguing that he wouldn't sell his soul for the pittance they paid him. Higher powers must judge the tangled commitments wrought by such employment; I will only observe that we generally, and with good reason, require institutional impartiality as a prerequisite for genuine objectivity of mind.

The longstanding reason is more interesting intellectually and permits us to work back toward Fisher's first great error, thereby revealing an important continuity in his life and career. Fisher was a strong, lifelong supporter of eugenics, the proposition that human life and culture could be bettered by implementing strategies for genetic improvement by selective breeding—either encouraging childbearing by those judged genetically more fit (positive eugenics) or preventing procreation by the supposedly unfit (negative eugenics). I must emphasize at the start that I do not single out Fisher for any special opprobrium on this score. The great majority of geneticists advocated some form of eugenics, at least until Hitler showed so graphically how a ruthless pro-



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gram of negative eugenics might operate. Moreover, Fisher's idiosyncratic version was relatively benign politically and largely in the positive mode. Eugenics was a big and motley movement, including its fascists to be sure, but also its idealistic socialists and committed democrats.

Fisher's strong and lifelong preference for genetic explanations of behavior, the foundation of his eugenic sympathies, surely predisposed him to the argument that both smoking and cancer might be linked to genetic variation among people. The same preference for genetic explanations inspired his much more extensive and encompassing first great error—his general theory of racial decline (and possible eugenic salvation), as presented in his *magnum opus* of 1930, *The Genetical Theory of Natural Selection*.

Just as most of my colleagues ignore Fisher's late and embarrassing work on smoking, they also pay little or no attention to the eugenic chapters of our profession's bible. Evolutionists may not know much about Fisher's campaign to exonerate the tobacco industry, but how can they bypass several chapters of a crucial volume present in every professional's library? One leading book on the history of population genetics says this and no more about Fisher's eugenic chapters: "In the

concluding five chapters he extended his genetical ideas to human populations."

We don't like to admit flaws in our saints. Perhaps my colleagues are embarrassed that a truly great work, the abstract and theoretical foundation of our field, should include a practical view of society that most of us find both fatally flawed and politically unacceptable. Perhaps we tend to view the eugenic chapters as an unfortunate and discardable appendage to a great work of very different character. But such dismissal cannot be defended. The eugenic chapters are no ending frill; they represent more than one-third of the book. Moreover, Fisher explicitly insists that these chapters follow directly from his general theory and cannot be separated from his more abstract conclusions. He states that he only gathered these chapters together for convenience and that he might, instead, have scattered the eugenic material throughout the book. Fisher writes: "The deductions respecting man are strictly inseparable from the more general chapters."

A single, if complex, argument runs through the five eugenic chapters: advanced civilizations destroy themselves by "the social promotion of the relatively infertile," that is, people who rise into the ruling classes (the "better people" so nec-

essary to successful government) tend, alas, to have fewer children for reasons of relative genetic infertility, not mere (and reversible) social choice. The upper classes therefore deplete themselves, and society eventually weakens and crumbles. If this assertion seems implausible a priori, then follow Fisher's rationale through six steps. Again, as with smoking, the argument is impeccably logical, in the narrow, technical sense of following from its premises, but entirely wrong, almost nonsensical, based on the fallacy of those key premises.

1. All great civilizations cycle from initial prosperity to eventual decline and fall. Although conquest may terminate a depleted race, the cause of decline is internal and intrinsic. The major reason for ultimate failure must lie with a predictable weakening of the elite classes. Can this decline be stemmed and stability with greatness imparted? Fisher writes: "The fact of the decline of past civilizations is the most patent in history. . . . The immediate cause of decay must be the degeneration or depletion of the ruling classes."

2. Fisher now notes, but misinterprets, the well-documented relationship between family size and social status in modern Western nations. Poorer families have more children, while the elite are rela-

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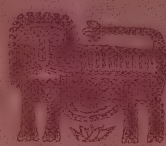
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tively infertile because they marry later, have fewer children after marriage, and contain a higher percentage of individuals who remain bachelors or spinsters. This relative infertility of the upper classes leads to their depletion and, eventually, to a decline of civilization by failure of the most able to replenish themselves. Fisher writes: "The birth rate is much higher in the poorer than in the more prosperous classes, and this difference has been increasing in recent generations."

Interestingly, and on this basis, Fisher rejects the two most common alternative explanations for racial decay advanced by eugenicists of his time. He denies, first, that the upper classes alone are being vitiated by dangerous inbreeding. The decline in fertility is gradual and pervasive through the social hierarchy, not confined to the ruling elite. Fisher writes:

The deficiency in procreation is not especially characteristic of titled families or of the higher intellects, but is a graded quality extending by a regular declivity from the top to the bottom of the social scale.

Secondly, Fisher also rejected the common argument with the most unfortunate moral and political consequences—that superior civilizations decay by racial mixture with inferior groups. Fisher's rejection arises directly from his general evolutionary views—and this link supplies the best proof that Fisher's eugenic chapters are integrally connected with his theoretical work in evolution, and that the two parts of his book cannot be separated, with the theory exalted and the eugenics ignored in embarrassment. The book's centerpiece is a proposition now known as Fisher's fundamental theorem of natural selection—"the rate of increase in fitness of any organism at any time is equal to its genetic variance in fitness at that time." Or roughly, the rate of evolution by natural selection is directly proportional to the amount of usable genetic variation maintained in a population. Or even more roughly, genetic variation is a good thing if you want to accelerate the rate of evolution. Therefore, since eugenic betterment requires effective evolution, anything that boosts the amount of usable variation should be strongly desirable in Fisher's view. Racial mixing represents a powerful way to increase variation, and Fisher had to acknowledge its potential benefits. (Fisher, following a common prejudice of his time, did not deny the general superiority of some races. Thus, race mixture might lower the average quality of a people. Nonetheless, the *range* of variation would increase, even while the mean declined, and natural selection could pro-

duce improvement by favoring rare individuals on the extended upper end.)

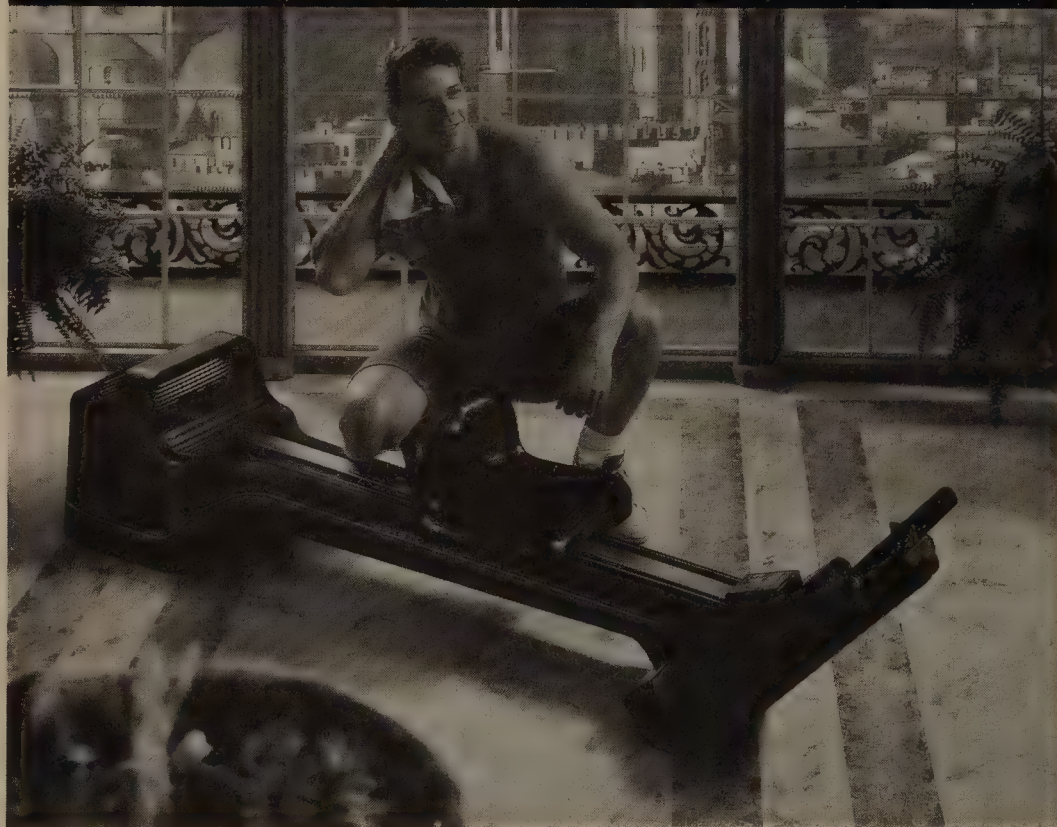
3. One might think that the elite have fewer children for purely social reasons (greater access to contraception, postponement of childbearing for work or education, more access to types of leisure better enjoyed without large families), but in fact, the cause of the correlation is largely genetic and the elite are less fertile for constitutional reasons.

This statement is the centerpiece of Fisher's eugenics. He argues that the low fertility of modern elites is a pernicious and recent development, not a permanent state of all societies. In "primitive" social organizations, rulers generally have *more*

children. (Fisher discreetly bypasses the major reasons for this former positive correlation—concubinage and multiple marriage by males in power—largely, I suspect, because he rejects such practices morally and so much wishes to think well of elites in any age!) Fisher writes: "The normal destiny of accumulated wealth was to provide for a numerous posterity."

But "advanced" civilization has reversed this old and biologically healthy correlation. The elite now have fewer children, primarily for reasons of relative genetic infertility. How did the tragic reversal occur? Fisher argues that tendencies for social promotion of the less fertile predictably arise in advanced civilizations,

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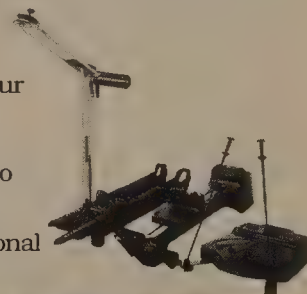


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thus flooding the upper classes with the source of their eventual depletion. But how could such a tendency originate?

4. People who rise from the lower to the upper classes (in a democracy that allows such mobility) do so by virtue of genetic superiority and the advantages thus conferred via intelligence and business acumen. But, unfortunately, these people also tend to be less fertile. Fisher's argument here exactly follows the form of his later claim for smoking. High ability does not cause infertility, nor does infertility produce brilliance. Rather, the correlation of high ability and infertility originates because both traits are independently linked to a pernicious circumstance that arises only in advanced civilizations. You have to possess strong, genetically based ability in order to rise at all. But if you also come from a large family (and therefore inherit a propensity for high fertility), your chances of rising are diminished because your family will be poorer (more mouths to feed, all other things being equal) and you will have less access to education. But if you have the same high ability and also come from a small family (with heritable low fertility), you gain a better chance to rise. By this noncausal correlation of ability and infertility, the chief reason for declining civilization emerges: the social promotion of the relatively infertile.

The situation breeds tragedy all around. The lower classes decline by loss of their most able members; the upper classes sink by the infertility of these upwardly mobile people. Society goes down the tubes. Fisher, at least, attempted to do his personal bit to stem the tide by raising a bevy of kids.

5. Fisher now faced a problem in the logic of his argument. If the upper classes are so infertile, shouldn't rising immigrants from lower levels help to replenish the dearth even if they are less fertile than their compatriots remaining at the bottom? Fisher, following a curious argument first advanced by Francis Galton, argued that men who rise by ability tend to marry particularly infertile upper-class women, thus diluting their own capacity for childbearing. Such men, knowing their advantages and being clever enough to exploit them, tend to marry heiresses should the opportunity arise (for they so desperately need a financial leg up in order to use their considerable abilities). Now an heiress tends to be particularly infertile because she is so often the only child in a family. Fisher laments: "This puts in the same class the children of comparatively infertile parents and the men of ability, and their intermarriage has the result of uniting sterility and ability."

When you dissect this preciously ab-

surd argument for its hidden assumptions, sexist and otherwise, you get some sense of Fisher's own background and social biases. You realize how illusory must be the notion of absolute impartiality—of obedience only to the logic of argument and the dictates of empirical data. Only men do the rising from lower classes. Infertility is the burden and fault of women. In other words, men advance and women then pull the whole family line down.

6. Fisher summarized the baneful effect of the genetically based inverse correlation of childbearing and social status:

Whenever, then, the socially lower occupations are the more fertile, we must face a paradox that the biologically successful members of our society are to be found principally among its social failures, and equally that classes of persons who are prosperous and socially successful are, on the whole, the biological failures, the unfit of the struggle for existence, doomed more or less speedily, according to their social distinction, to be eradicated from the human stock.

If the social promotion of infertility is the cause of this destructive inverse correlation, then our only hope for reversal and salvation lies in legislated policies aimed at social *promotion* of the *more fertile*. Fisher advocated some form of payments for childbearing, so that lower-class people of both ability *and* fertility would be able to rise—as I said at the outset, a relatively benign form of eugenics.

I need hardly detail the numerous false assumptions that derail Fisher's complex argument. I only note that they represent exactly the same mistake—uncritical acceptance of genetic conjectures—that invalidated his later case for smoking. Why should we assume that people who rise socially do so, in large part, by genetic endowment? And even if this argument is valid, why assume that the well-known negative correlation of childbearing and social status results from differential *genetic* fertility, especially when so many excellent and obviously nongenetic explanations cry out for attention (although Fisher mentions them only in quick derision), including, as mentioned before, longer years of schooling, delayed marriage, and greater access to contraception and abortion. The first genetic conjecture (a biological basis for social promotion) seems less implausible, although quite unproved; but the second conjecture (a genetic basis for fewer children in the upper classes) seems wildly improbable and even borders on the absurd. Yet Fisher's case absolutely requires that both genetic conjectures be valid, for if we rise genetically but then have fewer children only for so-



cial reasons, then his argument falls apart, since no "social promotion of infertility" would exist.

We may take a kindly view of Fisher's eugenics and say that his genetic conjectures did no harm, for try as he might—in press and before Parliament—Fisher's recommendations made no practical headway. But false genetic hypotheses of human behaviors and statuses are politically potent. They represent an ultimate weapon for social conservatives who wish to "blame the victim" for any correctable social ill or inequity. Are workplaces toxic? Screen workers and fire those with genetic predispositions to react badly. Is adequate access available to members of minority races? Argue that they are inferior by nature and therefore already occupy an appropriate number of slots. The genetic fallacy is generic—and applicable almost anywhere for the common and lamentable social aim of preserving an unfair status quo.

We may excuse Fisher's eugenics as relatively harmless, but we cannot be so sanguine about his campaign against a causal link between cancer and smoking. Joan Fisher Box wrote a fine biography of her father, marred only by an understandably hagiographical approach. She depicts Fisher's smoking campaign as rousing good fun for her father, a kind of harmless little game enjoyed by a gadfly against powerful interests. But her last paragraph on this topic is chilling, unintentionally so I suspect:

In 1958 Fisher was brought into discussion of the evidence in the United States in connection with legal suits expected to be brought to trial against tobacco manufacturers for personal damage caused by their products. Early in 1960 he visited the United States at the invitation of a legal firm representing an American tobacco company, whose case was brought to trial in April that year. Other suits were either not brought or were unsuccessful, and the legal pressure on tobacco companies was relieved for a time.

And that, friends, translates into many, many deaths—as pressure to quit and to restrict advertising diminished. Fisher may have been only the tiniest cog in a great machine rolled out by the tobacco industry, but he did contribute. Charles Lamb once wrote a humorous couplet:

For thy sake, Tobacco, I
Would do anything but die.

Bad and biased arguments can have serious, even deadly, consequences.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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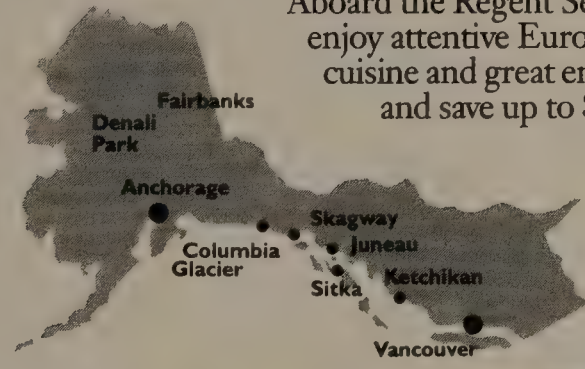




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REGENCY  CRUISES

Buffalo Beats, Ohio

by Robert H. Mohlenbrock

In 1935, botanist Edward N. Transeau described patches of prairie found east of the Great Plains, in Michigan, Illinois, Indiana, and Ohio. He believed these isolated patches were remnants of what had once been an arm of prairieland, which he called the prairie peninsula. One of the easternmost of these patches, called Buffalo Beats, lies near Athens in southeastern Ohio, on land now part of Wayne National Forest. It is named for the American bison, which may well have grazed there when it roamed this part of Ohio.

I visited Buffalo Beats one warm May afternoon in the company of forest ranger Joe Newcomb and botanist Marilyn Ortt of the Ohio Heritage Program, an organization that assists the Forest Service in managing the prairie. After a short but steep climb through a dense forest of black, scarlet, and white oaks, we reached the top of a ridge where the forest ended abruptly and a half acre of prairie vegetation was exposed to sunlight. The clearing was pink with hairy phlox in full bloom, punctuated by an occasional splash of orange from false dandelions, yellow from cinquefoils, and gold from golden alexanders. Leaves of many other species were evident, some just beginning to unfold: blazing-star, yellow gentian, rattlesnake-master, stiff goldenrod, whorled rosinweed, and the dominant grasses (big bluestem and Indian grass) would be flowering vigorously by autumn.

Lifelong residents of the area recall that this forest opening existed during their childhood, and several botanists have traced its condition for more than half a century. Howard Wistendahl described Buffalo Beats in 1962, when it covered about two acres. To help explain the presence of prairie plants in the heart of the predominantly oak forest, Wistendahl examined the soil. He noted that the dense forest, with its oaks and an understory of maple-leaved viburnum, grew on a light-colored, shaly soil, while the prairie had

developed on a layer of dark red clay that was deposited several inches deep over the shaly soil. The clay held more water, provided more nutrients, and was less acidic than the adjacent forest soil.

The clay was deepest at the center of the prairie and thinned out at its border. Wistendahl defined three zones of vegetation. The prairie, devoid of all trees, occupied the deeper red clay. A forest with an understory of mixed forest and prairie species grew where only a thin layer of red clay covered the shaly soil. Beyond this "transition zone" was the regular forest.

Two decades after Wistendahl's work, Dennis Hardin restudied Buffalo Beats and discovered that the forest had encroached so much that only about a half acre of reasonably intact prairie remained. Even there, woodland trees, shrubs, and herbaceous plants were invading. Two prairie species, the whorled rosinweed and the milk spurge, had become more common, and several others, includ-

ing the hairy sunflower, continued to flourish in the transition zone. But rarer prairie herbs had become still rarer, and big bluestem, the dominant prairie grass, had decreased from 50 percent of the cover to only 16 percent.

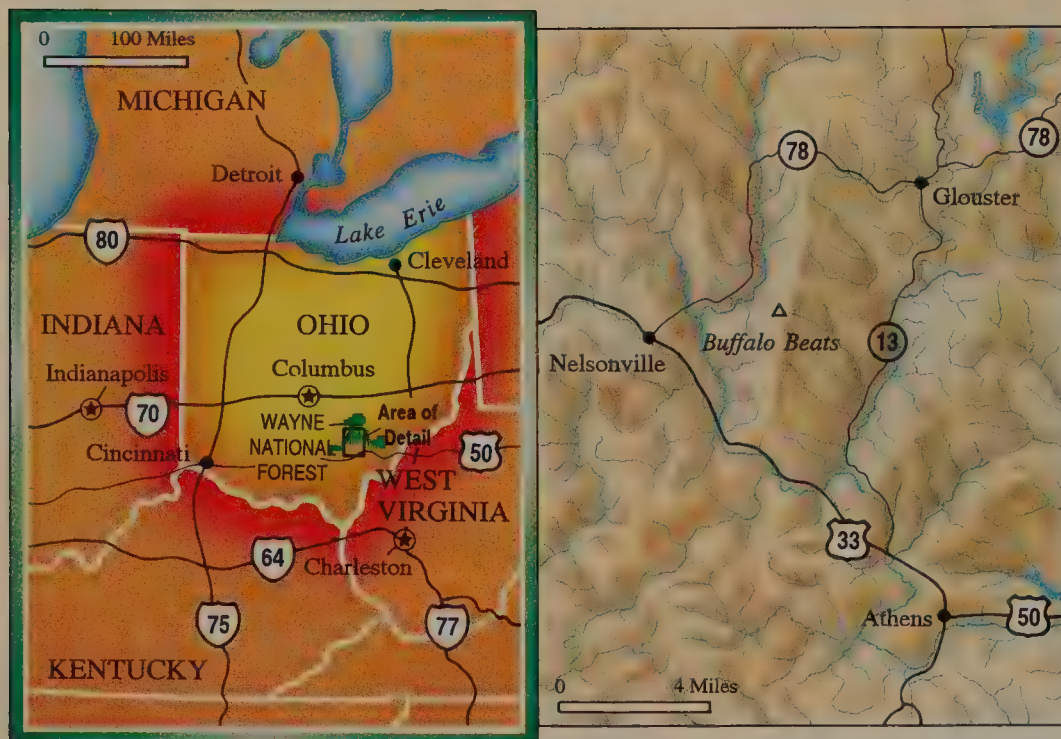
To halt the advance of the forest, Hardin recommended a management plan, which the Forest Service and the Ohio Heritage Program are now implementing. In early spring of 1986, fifty trees with a diameter of six inches or more were cut down within the prairie and removed, along with some woody plants in the transition zone. One huge branch of an oak tree that extended halfway across the prairie was also pruned because the shade it cast encouraged the growth of forest species. These steps aided the growth of some prairie plants during the spring and summer but also brought an unwelcome influx of poison ivy, which, along with woody seedlings and stump sprouts, is now being weeded out periodically by hand.



The half acre of prairie known as Buffalo Beats, above, lies in the heart of an oak forest. Opposite: A hairy sunflower

Marilyn Ortt





Despite the increased exposure to sunlight following the tree cutting, many prairie plants in Buffalo Beats still did not flower or set seeds. As a further experiment, during the spring of 1987 the southern half of the prairie was burned. This triggered rattlesnake-masters, yellow gentians, hairy sunflowers, and stiff goldenrods to bloom profusely that summer and autumn, and they have continued to do so in the years since. The management team is reluctant to burn the entire prairie, however, for fear of destroying the insect population. Entomologists have found that Buffalo Beats is a haven for insects, including some very uncommon ones. Two species unique to the area seem to depend

completely on the subulate phlox that grows there.

The questions of the origin and age of Buffalo Beats have intrigued botanists for years. In 1942 ecologist Paul Sears suggested that the warming trend that ended the last Ice Age some 12,000 years ago may have eventually rendered the climate in the eastern United States hotter and drier than it is today, allowing the development of Transeau's "prairie peninsula." But how can we tell whether Buffalo Beats is a remnant of this ancient prairie or a more recent colonization by prairie plants of an artificial forest clearing?

A recently developed technique has helped resolve this question. Plants take

Buffalo Beats

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up silicon from the soil and eventually deposit it in their leaves as granules of silicon dioxide known as opaline phytoliths. These microscopic phytoliths, which differ in shape among groups and species of plants, may persist in the soil for as much as 13,000 years. Forest soil scientists P. J. Kalisz and S. E. Boettcher took soil samples in and around Buffalo Beats and discovered that the phytoliths found in the prairie soil were almost exclusively from nonwoody, prairie-type species, while those in the transition zone were from a mixture of prairie and forest plants, and those in the forest soil were almost exclusively produced by trees. They concluded that the prairie had occupied the ridgetop for at least 13,000 years and probably once extended over what is now called the transition zone.

The existence of a virgin patch of prairie in this region is remarkable, considering that all other tillable tracts have at least been tried for agriculture. Marilyn Ortt has studied the ownership of the land as far back as the records go and found that except for an inconsequential three-day period, the land has belonged to absentee owners who were not around to farm this small parcel. Recently, in a fine gesture of conservation, the Quaker State Corporation, which owns the mineral rights beneath Buffalo Beats, gave up its claim in an agreement signed with the Forest Service. As a result, there is renewed hope that the tiny prairie will be preserved for future generations.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U. S. national forests.



An oil pump remains nearby, but Quaker State has relinquished its mineral rights in a move to save this prairie.

Jeffrey Blaufarb

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Saint George and John Canoe

The Caribbean is haunted by the ghosts of Christmas past

by Samuel M. Wilson

The village of Gingerland is strung out along a couple of roads on the small Caribbean island of Nevis. The main route around the island passes through the village, another heads down to the sea, and a third turns inland toward the island's 3,000-foot-tall volcanic cone. The dominant buildings are two stone churches; near the village center, a bridge crosses a ravine, filled with breadfruit and papaya trees, and small shops line the road. Some inhabitants of Gingerland's large cemetery lived and died when Nevis was the center of Britain's New World empire and the North American colonies were but the troublesome and unprofitable periphery. A few hundred people, more or less, live in the village, depending on where you draw its boundaries. But at Christmas, people from all over Nevis and the surrounding islands come here to see the masquerade.

The "captain"—an older man well known in the community—leads a dozen or so costumed male dancers through the village. These men wear colorful shirts and trousers, or sometimes skirts, on which small mirrors and bells have been sewn. Trailing ribbons decorated with more flashing mirrors and tinkling bells, they dance to the rhythm of two drums (a deep kettledrum and a deeper bass) and a simple wood or tin fife.

Other groups of dancers wear far more elaborate costumes, with crowns of peacock feathers and striking gowns. Still others are dressed in parodies of European clothes of another era and masks of wire mesh painted a startling pink. Some athletic dancers wear minimal costumes and carry bows and arrows; as they dance wildly, the most adept throw tomahawks into the air and catch them without looking. The devilish protagonist of the island's popular "bull play" may appear, dressed in a red suit and fierce mask with bull's horns attached.

At first the music sounds like a military



A reveler, costumed as a lionfish, dances in a New Year's "Junkanoo" parade in Nassau, Bahamas.

Joe Viesti; Viesti Associates, Inc.

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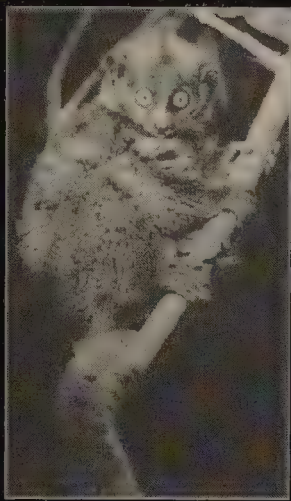


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march, but the fife has an exaggerated and somewhat satirical air. The music shifts, and the dancers glide into a stylized waltz; as the beat accelerates, men and women dance a hot rumba, very close to each other but not touching. At each change the music stops abruptly, freezing the dancers in their steps. Here is the cast of Nevis's historical drama over the last five centuries—people whose ancestors were from Africa, Europe, and the New World itself. The masquerade features them all, and the music and dance tell stories of the ways they interacted.

Because of the holiday season, December is the time of year when stories of the past seem to have special importance. In North America, as elsewhere, to celebrate Christmas, trees are forced through living room doors and loaded down with an anthropologist's dream of symbolic ornaments—birds, donkeys, candles, stars, and sleighs with fat, bearded gentlemen in strange red suits. Mistletoe is hung and rings of ornamented foliage are placed on doors. To celebrate Hanukkah, the candles of the menorah are lighted one by one and the dreidel is spun. All these things demand the recitation of stories that account for them, although sometimes the traditions that give meaning to the customs are nearly lost from everyone's memory. (Who was King Wenceslaus, anyway? And what's a dreidel?)

In the Caribbean, traditions are different from island to island, and Gingerland's masquerade is just one of many observances. In 1774, Edward Long described a Jamaican masquerade featuring an important character called John Canoe:

In the towns, during Christmas holidays, they have several tall robust fellows dressed up in grotesque habits, and a pair of ox-horns on their head, sprouting from the top of a horrid sort of visor, or mask, which about the mouth is rendered very terrific with large boar-tusks. The masquerader, carrying a woddin sword in his hand, is followed with a numerous crowd of drunken women, who refresh him frequently with a cup of aniseed-water, whilst he dances at every door, bellowing out *John Connú!* with great vehemence [*The History of Jamaica*].

Who is John Canoe? Edward Long thought he represented John Conny, a celebrated African king involved with the Prussians in the slave trade ("Conny" is a corruption of the German *König*, or "king"). In 1816, however, "Monk" Lewis described John Canoe in less fearsome terms, "dressed in a striped doublet, and bearing upon his head a kind of paste-board house-boat, filled with puppets, representing, some sailors, other soldiers, others again slaves at work on a planta-

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tion, &c" (*Journal of a West India Proprietor*). Perhaps the dancer and his headpiece represented the slave trade itself, with soldiers and sailors taking Africans into bondage. Some speculate instead that the character of John Canoe was modeled after Noah, who saved humankind from the Old Testament deluge.

Another amateur historian, I. M. Belisario, writing in 1837, says that the name John Canoe is a corruption of the French *gens inconnus* (unknown folks) and refers to the movement of French speakers from Haiti to Jamaica in 1795. Some elements from Haiti did indeed enter the festivities after that time. One such, important to the John Canoe celebrations in the nineteenth and early twentieth centuries, was the parade of "set-girls," groups of young women who dressed in elaborate formal gowns, "pin for pin alike, and carried umbrellas or parasols of the same color and size, held over their nice showy, well-put-on toques" (*Tom Cringle's Log*, 1836).

There is an older John Canoe, however. In *Jamaica Talk* (1961), linguist Frederic Cassidy argues that the name is what is important, and that the boat (like many parts of the performance) was added later. In the West African language Ewe, which is spoken today in Nigeria and is related to

several West Coast languages, *dzhon* means a sorcerer or magician and *kúnu* means something terrible that can cause death. The combined form, *dzhon'ko-nu*, means a powerful and dangerous shaman. In Jamaica and elsewhere in the Caribbean, and in most of the rest of the African American New World, such a person is now generally called an Obeah-man.

John Canoe was one of many West African contributions to Jamaican culture. To cite just one other example, the most popular Jamaican folk tales are stories of Anancy, the trickster spider; they deal with the same plots and themes as the stories of West Africa's *anansesem* (spider stories), sometimes mirroring them nearly word for word. The similarities are remarkable, considering that the ancestors of those now living in Africa and the New World parted company in Thomas Jefferson's time or before.

Jamaican stories and performances rework African themes and weave them together with elements of Judeo-Christian, Native American, and even classical traditions. "Monk" Lewis, in his journal for 1815, records a John Canoe celebration in which the figures on parade included Britannia carrying a trident and the coat of arms of Great Britain (portrayed by a horribly embarrassed young woman), the

king and queen, Admiral Lord Nelson, and British mummers. The Yoruba god Ogun, patron of smiths and metalworking, may appear in the form of (or sometimes alongside) Saint George, Saint James, or Saint John. Others who have proved popular over the years include Nanny and Cudjoe, revered leaders of Jamaican maroons (blacks who escaped slavery and set up free communities in the mountains), as well as General Jackson, who brutally put down a rebellion in 1865.

So who is John Canoe—an African king in league with Prussians, a biblical Noah, a leader of Haitian "unknown folk," a West African Obeah-man, or some other, unidentified personality? The only answer that is accurate and faithful to John Canoe's complicated origins is that he is a Jamaican. The Jamaican tradition of John Canoe combines all the contributing sources.

Such fusions are found in all Caribbean holiday pageants. Recent Christmas plays on Nevis have featured, among many others, David and Goliath, Saint George and the dragon, Mussolini and Haile Selassie, Ferdinand and Isabella, Moses and the children of Israel, mummies, and a multifaceted character named the Black Prince of Palestine.

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them (or maybe vice versa). Now the Christmas dances themselves are becoming less popular: Gingerland's Christmas fame has declined greatly in the last generation. In *Christmas Sports in St. Kitts-Nevis* (1984), Kittitian-born Frank Mills says, "The overwhelming majority of Kittitians and Nevisians under thirty years of age have never heard of half the different kinds of sports mentioned, and have witnessed even fewer. And there are many nationals over fifty who can add perhaps another dozen [to the eight I have described]."

John Canoe too is becoming a forgotten figure. Even in the early 1800s, the John Canoe dance in Jamaica was coming under pressure to change. The Reverend R. Bickell, an abolitionist, said that "most of those who had become Christians were ashamed to join in it" (*The West Indies As They Are; or A Real Picture of Slavery*, 1825). This adds weight to the interpretation that, at least in part, John Canoe voiced a people's resistance to an inhumane system and signaled their allegiance to an African past at a time of the year when they were able to express themselves most freely. The powerful and disturbing John Canoe became less important at about the time of the abolition of slavery in the British colonies in 1834. Once the centerpiece of the celebration, he became the headliner for an increasingly diverse performance, then a member of the cast, and eventually a character whose story few can remember in any detail.

In 1951 there was an attempt to revive the John Canoe dance with all its characters, and again dissension was voiced. One letter to the editor of Jamaica's *Daily Gleaner* said that "Juncunoo" was obscene, and "many people were taken to court for dancing horse-head, it was so vulgar." We need not lament the passing of this tradition, however. More than likely, the spirit of John Canoe—woven in new ways into the constantly changing West Indian traditions—has been so transformed that despite his presence we no longer recognize him.

Samuel M. Wilson teaches anthropology at the University of Texas at Austin.

Jamaican slaves formed "sets" that competed for superiority in music, costume, and beauty.

I.M. Belisario, from the Institute of Jamaica Collection

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On the way to greener feeding grounds, a seasonally migrating herd of Diplodocus moves through a landscape sparsely vegetated with cycads.

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In December, the American Museum of Natural History will unveil its reconstruction of the dinosaur *Barosaurus* in the newly renovated Theodore Roosevelt Memorial Hall. This month's cover painting and special section on sauropods mark the opening of this permanent exhibition.



Life Styles of the Huge and Famous

The giant sauropods led superlative lives

by Peter Dodson

Sauropods, as paleontologist Walter Coombs observed, were beasts the size of whales, on legs of elephants, with tails of lizards, necks of giraffes, heads of horses, and nostrils of tapirs. In any description of these beasts, superlatives abound. Sauropods had the smallest brains relative to body weight of any group of dinosaurs, yet they were among the most successful of all dinosaurs. The first sauropods appeared in the Early Jurassic, almost 200 million years ago. They reached the peak of their worldwide diversity in the Late Jurassic, about 150 million years ago, and a few persisted to the dying moments of the Late Cretaceous, 66 million years ago. So far, their remains have been found on every continent except Antarctica. There were more genera of sauropods than of any other major group of dinosaurs. (A genus comprises a group of closely related species.) About ninety genera of sauropods have been named, but fewer than fifty are probably valid. Few sauropods are known from essentially complete remains, and skulls are especially rare. This is a problem of taphonomy, or burial: these animals were so large that, most likely, the tail, head, and feet rotted away before the whole carcass was buried. Complete burial could easily have taken several years.

Indeed, sheer size is the most remarkable characteristic of the sauropods. Even a small sauropod was thirty feet long and weighed six or more tons. And the biggest? We're still trying to figure that one out. The largest, almost complete *Diplodocus* skeleton found so far is about ninety feet long. Very incomplete remains discovered by "Dinosaur Jim" Jensen, of Brigham Young University, in the famous Dry Mesa Quarry in western Colorado in the 1970s suggest that the tallest sauropod was *Ultrasaurus*, perhaps some 55 feet high, and the longest was *Supersaurus*, which may have stretched 125 feet from nose to tip of tail. A recent contender for top honors, at a possible 140 feet, is *Seismosaurus*, discovered in 1985 in New Mexico and currently under excavation by Utah paleontologist David Gillette. Typical sauropods ranged in weight from ten to thirty tons. *Barosaurus* was a

heavily built sauropod, although perhaps only eighty feet long.

How did these giants live? What they lacked in brains, they made up in brawn. Gigantism was obviously part of their formula for success. But did they become too big for their own good? Could they support their bulk on land or did they languish in swamps, submerged up to their chins in water? What did they eat and how many hours a day did they spend eating it? Were they warmblooded? How did they reproduce? And how long did they live? Thinking about questions like these puts flesh on the bones and brings our heroes to life.

Sauropods were long thought to have been too large to move about freely on land and to have required water to help support their bodies. In 1971, after studying the anatomical structure of the creatures' limbs, feet, and rib cages, Robert Bakker, a paleontologist in Boulder, Colorado, made a strong case that sauropods were thoroughly adept, elephantlike terrestrial animals, not short-limbed, barrel-chested, aquatic beasts.

Bakker and I decided to examine the colorful outcrops of the Upper Jurassic Morrison Formation in Utah, Colorado, and Wyoming, where the remains of the ancient behemoths have been found in abundance. Along with our colleagues Kay Behrensmeyer, now of the Smithsonian Institution, and John McIntosh, of Wesleyan University, we discovered that the sauropod fossils were by no means confined to rocks that indicated the presence of ancient swamps or lakes. At the Cleveland-Lloyd Quarry in central Utah and again at Sheep Creek in southern Wyoming, we found that skeletons had come from limy pond deposits. At the beautiful tilting bas-relief of Dinosaur National Monument in Utah (where the American Museum's *Barosaurus* came from, as well as three other kinds of sauropods and five other kinds of dinosaurs) and in the picturesque cliffs of Garden Park near Cañon City, Colorado, the ancient bones are closely associated with river channels that flowed across the Jurassic landscape. But bright red and maroon sediments near Cañon City, near Fruita, Colorado, and at Como Bluff, Wyoming, all attest to dry sa-

vannalike conditions. We concluded that sauropods roamed across a broad spectrum of environments, going essentially where they pleased.

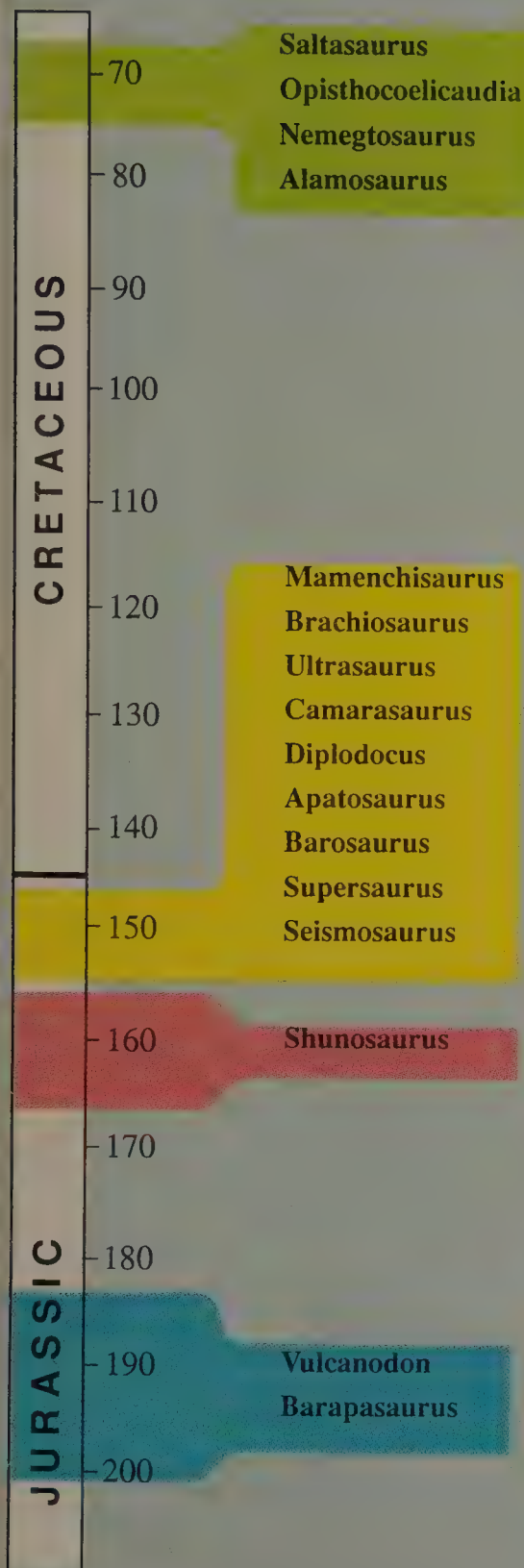
Furthermore, to our surprise, we found plant remains to be very uncommon. While large quantities of plant fodder were required to fuel sauropod bellies, little evidence of this verdure remained, having been oxidized to dust during the withering dry seasons. The bright hues of the Morrison sediments and the scarcity of plant remains contrast strongly with the pale colors and abundant plant remains in the Late Cretaceous beds of Alberta and Montana, where I have worked for the past ten years. During the Late Cretaceous, the lush lowland plains were awash with water. Seventy million years earlier, during the Late Jurassic, climates of western North America were dry and strongly seasonal. Sauropods may have wandered long distances following the rains in search of fresh salad.

But how much salad did a sauropod require? This depends on many things, but especially on body size and metabolic rate. A convenient size unit is elephant size, roughly five tons. The smallest Morrison sauropod, *Haplocanthosaurus*, weighed about one and a half elephant units. Slender *Diplodocus* weighed two or three elephant units, stocky *Camarasaurus* six elephant units, and bulky *Barosaurus* and *Apatosaurus* as much as eight elephants. The giants weighed in at ten to twenty elephants. Relative to their huge bodies, most sauropods had small heads, more or less the size of horse or giraffe heads. Also, the teeth, although robust and often heavily worn, particularly in the camarasaurids, are simple in structure.

How could a beast this big, with a relatively small head, have gathered enough food in a day to keep alive, much less thrive? Basically, the jaws and teeth were used simply to rake in foliage, which may have been reduced to small particle size internally in a gizzard. Sauropods may have also swallowed stones for grinding plants, but proof has been maddeningly difficult to come by. The West is almost paved with polished, egg-sized, sometimes brightly colored stones, which are com-

THE SIX SAUROPOD FAMILIES

Millions of years ago



Approximate dates for some representative genera of sauropods are given. Based on studies of their shared anatomical characteristics, sauropods are divided into at least fifty genera, which belong to six families.

VULCANODONTIDS

Remains of vulcanodontids have been found in rocks of Early Jurassic age in Zimbabwe and India, and some sauropods from Europe and China may also have belonged to this family. In size, vulcanodontids ranged from the diminutive twenty-foot-long *Vulcanodon* to the sixty-foot-long *Barapasaurus*. Much about this family remains unknown. We do know that they had distinctive spoon-shaped teeth covered with coarse projections, or denticles, that are unknown among other kinds of sauropods.



CETIOSAURIDS

Of moderate size, these sauropods ranged from forty to sixty feet in length. Most lived in the Middle and Late Jurassic, and fossils have been found on all continents except Antarctica. Cetiosaurid necks were not greatly elongated, and their front legs were just a little shorter than their hind legs. The Chinese *Shunosaurus*, the best preserved of all cetiosaurs, was equipped with a tail club. The only cetiosaur skull known belonged to *Shunosaurus*. It is long, with many spoon-shaped teeth; the nostrils, situated near the eyes, pointed sideways.



BRACHIOSAURIDS

Late Jurassic *Brachiosaurus* is the only thoroughly known member of this family. One of the heaviest of all dinosaurs, *Brachiosaurus* is famed for its long front legs and elevated shoulder region, which gave its back a sloping, giraffelike appearance. Its large nostrils sat in a bulge above the eyes. Its relative *Ultrasaurus* was large even for a brachiosaurid; it had an estimated vertical reach of fifty-five feet.



CAMARASAURIDS

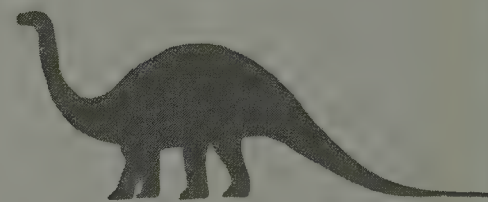
The most famous representative of this family is *Camarasaurus* from North America. *Camarasaurus* was a stocky sauropod, and neither its neck nor tail reached spectacular lengths. The neck vertebrae had large hollow spaces for lightness, and the neural spines above these vertebrae were split in two to allow for the passage of a strong ligament to help support the head. The skull was short, high, and

lightly built, and the teeth were spoon-shaped. Also known from Europe and Asia, camarasaurids first appeared in the Middle Jurassic, in the heyday of sauropods, but one member of this family, *Opisthocoelicaudia* from Mongolia, if correctly identified, lived in the Late Cretaceous, near the very end of the age of dinosaurs.



DIPLODOCIDS

This family includes the familiar giants *Diplodocus* and *Apatosaurus*, as well as *Barosaurus*. Most of these sauropods had extremely long necks and tails. *Diplodocus* was rather slender in build and reached a length of about ninety feet. The recently discovered sauropod record holders, *Supersaurus* and *Seismosaurus*, were members of this family and stretched to estimated lengths of 125 and 140 feet, respectively. *Barosaurus* had a longer neck than *Apatosaurus*, but the record neck was that of the Chinese *Mamenchisaurus*. At thirty-five feet long, its neck measured half the total length of its body. The diplodocid skulls known so far are long and low, with slender, peglike teeth that jut from the front of the mouth only. The nostrils were situated at the top of the skull, above the eyes. The last diplodocid appears to have been the Mongolian *Nemegtosaurus* from the Late Cretaceous.



TITANOSAURIDS

The most complete titanosaurid, *Alamosaurus*, with just one-quarter of its bones found, is also the only member of the family found in the United States. The best titanosaurid hunting grounds to date are in South America and India, where fragments of skeletons, many of Cretaceous age, have been excavated. Many members of this family were rather small; *Magyarosaurus* from Romania was a dwarf at only about thirty feet long. The Argentinean *Saltasaurus*, the only known armored sauropod, had a coat of bony scutes on its back.





Camarasaurus stride across a mud flat as a *Camptosaurus* herd passes in the distance. This painting is based on a trackway found in Colorado.

monly identified as “stomach stones”—even when dinosaur bones haven’t been found within a hundred miles of them. Rarely are such stones found with sauropod skeletons.

Unlike mammals, sauropods did not waste time chewing. After being processed in the stomach, food was slowly digested in the intestine. *Barosaurus* may have had six tons of fermenting plant material in its huge gut at any given time. Elephants in the wild ingest about 375 pounds of fodder over a twelve-hour day. For sauropods the setting sun may not necessarily have curtailed feeding. The need to consume many hundreds of pounds of greenery a day may have made sleep a luxury. We have learned from studies of mammals that large animals are generally unselective feeders. Everything goes down the hatch: scratchy leaves, woody twigs, and chewy bark, as well as tender shoots and fleshy fruits. In the Jurassic, flowering plants did not exist. Available plants included cycads, cycadeoids, conifers, ginkgoes, horsetails, and especially ferns. Prairies of ferns were essential features of middle Mesozoic landscapes, and ferns probably constituted a major component of sauropod diets.

Did sauropods also feed at the treetops, beyond the reach of other beasts? However appealing this image may be, it presents several problems. *Brachiosaurus* was built like a giraffe and may have fed like one. But most sauropods were built quite differently. At the base of the neck, a sauropod’s vertebral spines, unlike those of a giraffe, were weak and low and did not provide leverage for the muscles required to elevate and maintain the head in a high

position. Furthermore, the blood pressure required to pump blood up to the brain, thirty or more feet in the air, would have placed extraordinary demands on the heart (see opposite page) and would seemingly have placed the animals at severe risk of a stroke, an aneurysm, or some other circulatory disaster. If sauropods fed with the neck extended just a little above heart level, say from ground level up to fifteen feet, the blood pressure required would have been far more reasonable. The long neck may simply have served as a feeding boom for a stationary mountain of flesh. They could have lifted their heads with occasional graceful sweeps, blackout being prevented by using the carotid sinuses near the brain as reservoirs for blood. Sauropods were certainly capable of rearing up, or procreation would have ceased. But such a posture probably did not play a role in daily feeding activities.

Fossil footprints, sometimes arrayed in vast trackways consisting of hundreds or thousands of prints, attest to the herding behavior of sauropods. Fine examples of these have been found in Arkansas, Texas, and Colorado. Some of these have been studied by James Farlow, of Indiana University/Purdue University at Fort Wayne, and by Martin Lockley, of the University of Denver. The Davenport Ranch site in Texas is particularly informative. Here a few young individuals (with feet twelve inches across) were led by older individuals twice as large.

Their long legs would have made sauropods excellent walkers. Because the same kinds of sauropods are found over and over again from New Mexico to Montana, and because the Late Jurassic climate was

strongly seasonal with long dry periods, I believe that sauropods migrated widely on an annual cycle to follow the pattern of rainfall and plant regeneration.

Were sauropods warmblooded? Their temperatures were both high and almost constant. Climates of the Jurassic were warm, and sauropod body temperatures responded only very slowly, on a time scale of several weeks, to external temperature changes. But did they have high metabolic rates? This is the crux of the problem of understanding sauropod biology. Arguments about dinosaur metabolism are usually based on the physiology of tiny ectothermic lizards or endothermic mice. At large body size, however, the familiar differences begin to disappear. Unlike some of the smaller dinosaurs, the sauropods may not fit comfortably into warmblooded or coldblooded categories.

Biologists James Spotila, Frank Paladino, and Michael O’Connor discovered that the largest living sea turtle, the leatherback, has a metabolic rate nicely intermediate between those of typical reptiles and typical mammals. This metabolic strategy, which they called gigantothermy, permits leatherbacks an active life style. They migrate long distances every year and maintain warm body temperatures even in arctic waters. Yet they also enjoy the benefits of reptilian energy conservation. I joined these researchers on the Costa Rican beaches to observe 750-pound turtles drag themselves ashore to deposit their precious eggs under velvet, moonless tropical skies. Then we returned to our computers at Drexel University in Philadelphia to apply leatherback metabolic rates to sauropods. Our computer simulations suggest that a thirty-ton, or three-quarters grown, *Barosaurus* with a high mammalian-level metabolic rate would have been at severe risk of fatal overheating. As Warren Porter, of the University of Wisconsin, put it, an endothermic sauropod in full sunlight at noon would have suffered meltdown. With a leatherback metabolic rate, only maximum blood flow to the skin would have maintained the body temperature in a safe range. Our model and those of others working independently suggest that only a reptilian metabolic rate offered a safe physiological strategy for large sauropods, especially those living in warm, dry climates. The large size of sauropods is probably in itself an indication of low metabolic rate, life in the slow lane.

Were these giants long-lived? In general, longevity correlates positively with body size: large animals live longer than smaller ones, but coldblooded ones live longer than warmblooded ones of the

SAUROPODS AND GRAVITY

by Harvey B. Lillywhite

Gravity is a pervasive force in the environment and has dramatically shaped the evolution of plants and animals. For animals, life on land required muscular and skeletal adaptations to allow movement and mobility. Then, as some land animals evolved large body size and adopted an erect posture, cardiovascular specializations were needed to help them withstand the weight of blood in long vertical vessels. Perhaps nowhere in the history of life were these challenges greater than among the gigantic, long-necked sauropods.

The long-held view of sauropods as lumbering, aquatic swamp dwellers has been questioned on physiological grounds. In 1951, Kenneth Kermack pointed out that breathing would have been difficult or impossible for a sauropod up to its head in water, because pressure on the neck and chest, far under the water's surface, would not have allowed the creature to expand its lungs to inhale. Nonetheless, sauropods continued to be pictured almost completely submerged.

In the 1970s, Robert Bakker, following an idea first proposed by Elmer Riggs as early as 1904, reexamined sauropod anatomy and came up with a new vision of the creatures as enormous, giraffelike tree browsers, more gracile and agile than the sluggish giants popular in earlier depictions. In spite of their size, sauropods were conceivably well adapted for fully terrestrial locomotion and erect posture, although amphibious habits were perhaps equally likely, with wading sauropods sometimes using water for support. What remains unclear is whether sauropods on land held their head and neck erect or carried them lower, at the level of the body, as in the depiction of *Mamenchisaurus* mother and young below.

The farther away the head is from the heart, the more force must be exerted to pump blood up to it. An upright *Barosaurus* stood as tall as thirty-eight feet and had a neck length of some twenty-five feet. Consequently, in a *Barosaurus* with its head held high, the heart had to work

against a gravitational pressure of about 590mm of mercury (Hg). In order for the heart to eject blood into the arteries of the neck, its pressure must exceed that of the blood pushing against the opposite side of the outflow valve. Moreover, some additional pressure would have been needed to overcome the resistance of smaller vessels within the head for blood flow to meet the requirements of brain and facial tissues. Therefore, hearts of *Barosaurus* must have generated pressures at least six times greater than those of humans and three to four times greater than those of giraffes. (In a standing human the average arterial blood pressure is 95mm Hg at heart level.)

An animal contending with such high blood pressure would have needed strong arteries and greatly thickened heart muscle. Giraffes, for example, have the highest blood pressure measured in living vertebrates; compared with humans, they have relatively muscular arteries and thick-walled, enlarged hearts. Using a model that took into account heart wall stress and blood pressures, zoologist Roger Seymour estimated the heart size of large, erect sauropods to have been more than 1.6 metric tons, or eight times heavier than that of a similar-sized whale having a comparable internal heart volume. This may be an overestimate, however, because the structure of reptilian hearts allows a smaller wall thickness for a given stress than does a mammalian heart. Nonetheless, in most large dinosaurs, the ribs around the heart are long, suggesting that the cardiac compartment was indeed capacious.

If we look at living snakes, we see that arboreal or climbing species have evolved both high arterial blood pressure and heart positions that are closer to the head than in nonclimbing species. Proximity of the heart to the head presumably insures that blood flow to the head is adequate, regardless of body posture, and minimizes the height to which blood must be pumped when the snake's head is up. The anatomy of sauropods, however, did not allow anterior or

vertical migration of the heart into the neck. Therefore, natural selection for elongation of the neck must have outweighed the cardiovascular disadvantages, unless it preceded terrestrial habits.

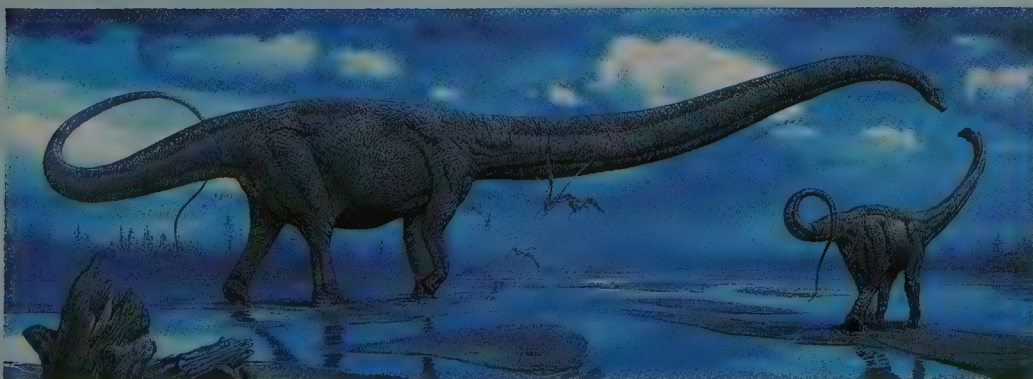
Because pressure increases with depth in any continuous fluid system, such as that in arteries, pressure in the legs of *Barosaurus* must have been greater than at heart level and could conceivably have reached 900 to 1,000mm Hg in the lower legs and feet. Such tremendous pressures pose serious dangers of tissue swelling due to excessive leakage of fluid from capillaries. Capillary pressures in the legs of *Barosaurus* were probably adjusted by muscular constriction of smaller arteries, which reduces downstream pressures. (Similar adjustments must have been required to regulate blood pressure in the brain whenever the head was lowered, for example, when the animal was drinking.) In giraffes, swelling is counteracted by the tight leg skin, which acts somewhat like support hose to raise pressures in underlying tissue fluids surrounding the capillaries and small vessels. The expansion of arteries can be partly counteracted by thickened, muscular walls. Other mechanisms that regulated the level of plasma proteins, rates of lymph flow, and placement of valves in veins might also have helped prevent swelling in the pillarlike legs of sauropods.

Finally, terrestrial sauropods would have required complex lungs, similar to those of living active reptiles or perhaps mammals. In all vertebrates studied so far, lung function depends on blood flow that is at uniformly low pressures (relative to the pressures in other parts of the animal). Sauropods, then, most likely had hearts capable of producing large differences in blood pressure between the lungs and other circuits of the body. This would have required either extreme modification of the resistance to blood flow somewhere between the heart and lungs or the evolution of a four-chambered heart as in crocodiles, birds, and mammals.

Perhaps no analogy with living animals will ever give us a true picture of exactly what was involved in such a monumental blood-delivery system as that of *Barosaurus* and its long-necked relatives. Nonetheless, paleophysiology can add to our understanding of the variety of animal designs possible, as well as evoke a richer picture of how the mammoth dinosaurs might have lived.

Harvey B. Lillywhite, a professor of zoology at the University of Florida at Gainesville, studies the physiology of snakes and other long-bodied animals.

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The longest-necked sauropod, *Mamenchisaurus*, crosses a mud flat.

Two Allosaurus pursue a young ultrasaur buffered by the pillarlike legs of adults. Sauropods, like elephants, may have traveled with the vulnerable young in the middle of the herd.

© 1988 John Gurche

same size. If sauropods had mammalian levels of metabolism, they probably grew quickly to maturity and had life spans of fifty to one hundred years at most. If they had reptilian metabolic rates, life spans would conceivably have been measured in centuries. Arthur Dunham, of the University of Pennsylvania, and his colleagues argued against warmbloodedness, but they believe that all dinosaurs were reproductively mature by the age of twenty at the latest, otherwise survival rates of the young would have to have been impossibly high to maintain the population.

Did *Barosaurus* lay eggs? As far as we know, *all* dinosaurs laid eggs. But we really don't know very much. Eggs and nests have been found in association with very few kinds of dinosaurs. The largest dinosaur eggs known, from southern France, have the volume of two-liter soda bottles and have been attributed to a small sauropod, *Hypselosaurus*. We have absolutely no direct evidence yet of the size of the eggs of the great sauropods. Eggs of the extinct elephant bird from Madagascar have five times the volume of the supposed *Hypselosaurus* eggs, so presumably no physiological reason prevented the development of even larger dinosaur eggs.

I view sauropods as somewhat stately, slow-moving titans. Others will disagree. Far from the pinnacle of dinosaur success, they were, I believe, archaic herbivores. Their large sizes, small heads, simple teeth, and tiny brains served them well for millions of years. But in the Cretaceous, more progressive, large-headed, larger-brained dinosaurs appeared, and vegetation changed. The moist lowlands of the Late Cretaceous, some 70 million years ago, had fast-growing, weedy, flowering plants and deciduous trees of small stature. In the drier habitats of the Jurassic where the sauropods thrived, the dominant plants grew more slowly. The teeth of Cretaceous duck-billed and horned dinosaurs were far more complex than those of sauropods and processed the food of the new flowering plants far more efficiently than sauropods ever could. The old giants retreated to southern continents, where the newcomers did not flourish. Nonetheless, some kinds of sauropods straggled on to the close of the age of dinosaurs. Skeletons such as the Museum's towering *Barosaurus* give testimony to one of nature's grandest extravagances. □





Barosaurus on Central Park West

*Old bones, shrewd deals, and engineering feats
result in a new display at the American Museum*

by Mark Norell, with Lowell W. Dingus and Eugene S. Gaffney

The time is about 150 million years ago; the place, a sparsely forested plain in an area that will one day become the arid mountains and deserts of western North America. A female *Barosaurus*, one of the largest animals ever to have walked the earth, and her offspring are peacefully feeding on plants. Suddenly, their foraging is cut short by the appearance of a hungry carnivore, *Allosaurus*. The lone hunter knows better than to attack the sixty-ton mother; pivoting, it rushes instead at the terrified baby. The young quarry attempts to hide behind its mother, dodging both her lashing tail and the *Allosaurus*'s deadly teeth and claws. In a final effort to protect her young, the *Barosaurus* rears up to a height of some fifty feet to fend off the attacker with her powerful forelegs or crush it under the weight of her immense body.

What is the sequel to this Jurassic drama? Maybe the giant *Barosaurus* mother is lucky and repels or kills the predator. Or perhaps the agile *Allosaurus* rips into the baby and proceeds to devour it as the mother flees in panic.

The effort to imagine dinosaurs as living organisms, facing challenges similar to those that confront animals today, was the inspiration for the new exhibit in the Theodore Roosevelt Memorial Hall, or Rotunda, of the American Museum of Natural History in New York. A mother *Barosaurus* towers above the Rotunda's floor, protecting her young from a predator. The dramatic and controversial pose gives viewers an idea of the dynamism that can reside in fossil relics. The effect produced by the most modern fabrication and fossil-mounting methods heightens both the romantic history and the grandeur of the fossils.

The story of how the *Barosaurus* came to the American Museum starts almost a hundred years ago. Much of the Museum's huge collection of dinosaur remains was assembled in the late 1800s and early 1900s, during what has been called the golden age of dinosaur exploration. When a mother lode of fossils began to emerge in the American West, the Museum and other natural history institutions in North America, competing openly to acquire ex-

tensive collections and discover new species, began a "bone rush."

Under the direction of Henry Fairfield Osborn, the first chairman of the Museum's Department of Vertebrate Paleontology, veteran bone hunters Walter Granger, Barnum Brown, and William Diller Matthew sent tons of fossils to New York. During the golden age, so much material was excavated that many specimens collected as long as a century ago still have not been thoroughly studied, prepared, or placed on public exhibition. Huge bones, some of them in their original wooden shipping cases, remain stored in the Museum's labyrinthine basement.

The dinosaurs in the Rotunda mount were found in the Morrison Formation, a fossil-rich rock unit stretching from New Mexico to Montana. This formation has yielded many remains of sauropods—the huge quadrupedal plant eaters, including *Barosaurus* and its relatives, that lived mainly in the Jurassic period, some 213 to 144 million years ago. *Barosaurus* is one of the rarest of all North American dinosaur fossils, and the adult and young on display are the only publicly exhibited specimens of these dinosaurs. The reconstructed adult, which is unusually complete for any dinosaur specimen known—80 percent of the material is original—is also the most complete specimen of a *Barosaurus* ever collected.

The adult was unearthed between 1912 and 1914 in what is now Dinosaur National Monument in Utah. It might have ended up as spare parts divided among three different institutions if not for the foresight and perseverance of Barnum Brown, the American Museum's foremost dinosaur collector.

About 1919, the heyday of collecting at this Utah site was drawing to a close when the principal excavator, Earl Douglass, of Pittsburgh's Carnegie Museum, discovered two remarkably well preserved sauropod skeletons. One of the skeletons went to the Smithsonian Institution, the other to the University of Utah. Later, when the University of Utah needed parts of a *Diplodocus* for a display, it traded a section of the *Barosaurus* tail to the Carnegie Museum for neck parts. The neck eventu-



Sauropod bones are embedded in rocks of the Morrison Formation in Dinosaur National Monument, Utah. A vast rock unit, the Morrison Formation is especially rich in sauropod fossils, many of which have not yet been excavated.

Willard Clay



FOSSIL HORSE TRADING

The following confidential memorandum from the archives of the American Museum of Natural History provides details on some of the exchanges that brought the widely dispersed Barosaurus skeleton to the American Museum:

REPORT ON BAROSAURUS

Supplementing my report of July 26, 1929. I again visited Salt Lake City in December and secured the following agreement from Dr. [Frederick J.] Pack who has authority from the President and Trustees of the University to act in their behalf in this negotiation.

Value of specimen agreed upon \$5000. Terms \$2,500 in cash, balance in trade.

Specimens desired by University of Utah: a three-toed horse skeleton (we can supply a composite skeleton), and other mammal material to make up difference. American Museum to box, ship and pay transportation charges on *Barosaurus*.

This agreement I consider fair with full value coming to the American Museum providing we can secure the remainder of this skeleton.

The part of this *Barosaurus* skeleton in the National Museum consists of the last ten cervical vertebrae with

ribs; three anterior dorsals; left scapula and humerus. It has cost \$3,400 to clean and restore it (Laboratory records).

[Charles W.] Gilmore (confidentially) favors an exchange and desires a free mountable skeleton of *Gorgosaurus*. Dr. [Alexander] Wetmore does not favor disposal of this *Barosaurus* neck (from conversation reported by Gilmore).

American Museum can offer the following specimen in exchange: *Gorgosaurus* No. 5434. Skull and jaws, all cervicals, and dorsal vertebrae, all ribs, forelimbs, one femur. Sacrum, hind limbs, except one femur, will be cast.

Cost of preparing and casting hind limbs and part of tail \$4,123. To finish tail and sacrum \$450.—total cost \$4,573. (Cost taken from Laboratory time sheets and exclusive of collecting and transportation charges).

The caudal series of this skeleton nine or ten vertebrae in the Carnegie Museum are preserved in two blocks, 348/A and 349/B according to their quarry charts.

So far no negotiations have been undertaken to secure this part of the specimen.

A.M.N.H.
Dec. 31, 1929

Barnum Brown

AMNH



Bone collector Barnum Brown and his wife, Lilian, at Howe Quarry in 1934

ally proved to belong not to a *Diplodocus* but to a *Barosaurus*.

As a result, the bones of the rare *Barosaurus* were dispersed to three different institutions. Barnum Brown, recognizing the skeleton's importance, came up with a plan to unite the bones in New York, even though the American Museum owned none of the material and had not even participated in its excavation and preparation. In 1929, Brown negotiated with the three institutions in an effort to consolidate the specimen in New York. According to some of his original correspondence, the deal called for a combination of fossil trades and cash payments between the American Museum, the Carnegie, the University of Utah, and the Smithsonian. In the end, Brown's bargaining helped the American Museum acquire the bones for far less than it would have cost to collect them in the field.

The Roosevelt Rotunda mount reflects the legacy of many early paleontologists and the efforts of contemporary scientists and fossil preparators. During our lunches here at the American Museum, Gene Gaffney, Lowell Dingus, and I—members of the Department of Vertebrate Paleontology—developed the idea of mounting a sauropod on its hind legs. The first drawings were blurry sketches made on damp napkins. In the beginning, none of us really believed that our wishful speculation would eventually lead to the reconstruction in the Rotunda.

After developing a preliminary design, we got to work. All the original bones, stored in the collection for sixty years, had to be cleaned and repaired. Many of their glue joints had cracked, and some of the pieces were scattered. Only about a fifth of the skeleton was missing, but each of these pieces, including the skull, several limb bones, and part of the tail, had to be modeled to complete the skeleton.

The replacement parts were modeled in Toronto, Canada, by Research Casting International, an organization that specializes in fabricating and mounting dinosaur casts. Under the direction of Peter May, the technicians at Research Casting sculpted each individual missing bone in clay, basing the shapes on the remains of more completely known close relatives of *Barosaurus*, in particular, its contemporary *Diplodocus*. According to John S. McIntosh of Wesleyan University, the premier scholar of sauropod relationships, this better-known Jurassic sauropod so closely resembles *Barosaurus* that many partial skeletons and isolated bones long considered by paleontologists to be the remains of the rather common *Diplodocus* may actually belong to *Barosaurus*.



The Museum's adult *Barosaurus* was fabricated bone by bone by the technicians of Research Casting International in Toronto, Canada. Molds of each bone were cast, top, and then mounted, below.

Photographs by Paul von Balch



The weight of the original *Barosaurus* bones—a single vertebra weighs up to 200 pounds—would have made mounting the actual fossils impossible without thick structural supports. In addition, the pose of the adult *Barosaurus* in its rearing stance of fifty feet above the Rotunda floor demanded the lightest of materials. So, after the modelers had sculpted the missing elements, they made a duplicate of the *Barosaurus* bones by coating them with latex, which, when cured, formed a rubber mold. These molds were cast with polyurethane foam to provide sturdy but light replicas of the original fossils. Those that would stand near the ground were cast in higher-density and more durable materials, while those higher up were made of lighter substances. The weight of the neck vertebrae seems to have been a functional consideration even for the living *Barosaurus*. The sauropod solution was the development of large pleurocoels, or air spaces, in the vertebrae, which lightened the bones without compromising strength. The extreme complexity of these vertebrae made them the most difficult part of the skeleton to mold and cast.

The construction of the juvenile sauropod presented its own problems. The only material in our collection consisted of some neck vertebrae and a crushed skull collected at Howe Quarry in north-central Wyoming. Discovered and excavated by Barnum Brown, Howe Quarry was one of the richest accumulations of dinosaur remains ever found. Unfortunately, most of the material found was disarticulated, lying in a large jumble of bones, so determining what bones belonged to what animal was problematic.

Because the juvenile *Barosaurus* is so fragmentary, most of the body needed to be sculpted in clay and then cast. Bone shapes and proportions were determined from more complete skeletons of closely related species. However, juvenile and baby animals are not just miniature adults; many of the differences that distinguish an adult *Barosaurus* from an adult *Diplodocus* may not be apparent in the young. In the process of growth, bones change not only in size but also in shape and in relation to other bones in the skeleton, much as puppies' bodies grow at a relatively faster rate than their paws. Structural transformations, such as the appearance of antlers in adult deer, may also arise at various points. To reconstruct the skeleton of the young *Barosaurus*, we have attempted to use what little information we have concerning the body proportions and anatomical structure of these animals.

The third animal in the grouping, the

After sections of the bodies of the dinosaurs were mounted, technicians, engineers, and paleontologists moved their shop to an empty parking lot to piece together the entire skeletons. The darting *Allosaurus*, below, was eventually balanced by steel strung from one ankle. A few vital vertebrae still missing, the adult *Barosaurus* rears next to a cherry picker, right.

Photographs by Paul von Balch



sprinting *Allosaurus*, was the easiest to fabricate. Thanks to the discovery of a remarkable deposit, the Cleveland-Lloyd Quarry in central Utah, almost every bone in the skeleton is known. During the thirty years that it has been excavated by Jim Madsen, of the University of Utah, the quarry has produced the remains of scores of *Allosaurus* individuals of different size classes. Some paleontologists suspect that this *Allosaurus* graveyard is a remnant of a particularly dangerous river crossing or quicksand deposit that entrapped the agile carnivores.

Mounting the *Allosaurus* in its dynamic running posture was a more difficult task. Special steel, chosen in consultation with a structural engineer, was needed to create the armature, or supports. The steel at the ankle of the *Allosaurus* had to be strong so as to support the animal at an extreme angle from only a single point. The armature along the spine and the tail needed to be light but rigid. The finished product is an almost invisible framework strong enough to sup-

port fifty pounds hung from the tip of the tail with no deflection.

Finally, we had to choose what kind of base to mount the animals on. Because we do not know exactly what kind of terrain this battle may have been played out on 150 million years ago, we opted for a purely aesthetic choice. What better than a replica of actual fossil-producing rocks? During the summer of 1991, Gene Gaffney and Peter May located a likely site, a small hillock in the Paleocene Tullock Formation in eastern Montana. Moving a fragile clay section of land this size would have been a monumental effort, so a thin layer of latex rubber was sprayed over the terrain to form a large sheet mold. The mold was then sent to the shop of Research Casting International in Toronto, where it was cast and painted. This exact replica of a small piece of the Montana prairie now forms the base of the New York exhibit.

Probably the most controversial aspect of our mount is the pose of the dinosaurs themselves. Was *Barosaurus* capable of

standing on its hind legs? Would it have protected its young in this fashion? And would the *Allosaurus* have launched such an attack? Although much has been written recently about the behavior and capabilities of these Mesozoic giants, little actual evidence regarding their behavior and physical limitations can be determined from the bones themselves. While issues such as the diet, color, physiology, and behavior of various dinosaurs hold great appeal, any pronouncements on the habits of animals that went extinct more than 66 million years ago are highly speculative. Rigorous scientific tests of many current theories are not possible within the context of the available evidence—the fossils. So, while scenes like ours may seem spectacular and seductive, beware! They represent only one of the many possible scenarios that may have occurred 150 million years ago. Because they have long vanished from the earth, leaving no close living relatives that we can observe in the wild, the giant sauropods will always retain much of their mystery. □



It's time for a change to Gallo.

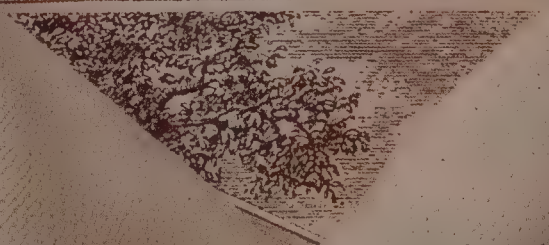




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This Bug's for You

by Steven N. Austad and Randy Thornhill

Photographs by Mark W. Moffett

Their bad reputation notwithstanding, female spiders rarely attack and devour their mates. Even in the case of the infamous black widow, if a male courts at the proper time and approaches the female with the proper caution, he will survive the encounter. The females of the species *Pisaura mirabilis*, however, do like to snack while they mate and will consider only a suitor bearing a large nuptial gift—in the form of a fat, juicy insect. The courtship ritual of this common European nursery web spider is unique among the 30,000 or so known species of spiders. Upon reaching maturity the males virtually cease eating. They turn solely to courtship, and instead of devouring the insects that they ambush, they carefully wrap the prey, clasp the silk-enshrouded corpses in their jaws, and set off in search of mates.

Once a male locates a female, he approaches her cautiously and tilts backward to present the prey held in his jaws. At the same time, he raises and vibrates his pedipalps (two short, leglike appendages on either side of his jaw, which contain special sperm storage sacs). The female passes her own pedipalps over the insect, as if measuring its size with calipers. She will summarily reject males bearing very small nuptial gifts and simply walk away. If the gift is acceptably large, the female bites into it and begins feeding, but she may walk away to eat it elsewhere, dragging the hapless male beneath her.

Once she is occupied with her meal, the male gingerly releases his grip on the prey and swivels underneath the female to insert a pedipalp into one of two openings in her abdomen. After mating for about an hour, he swivels back to his original



Grasping a katydid in his jaws, a male nursery web spider prepares to wrap his catch.



The spider below finishes wrapping his prey with thick bands of silk from his spinnerets. Right: Carrying the nuptial gift beneath him, the male (right) approaches a female. They tap with their first two pairs of legs to verify each other's identity.



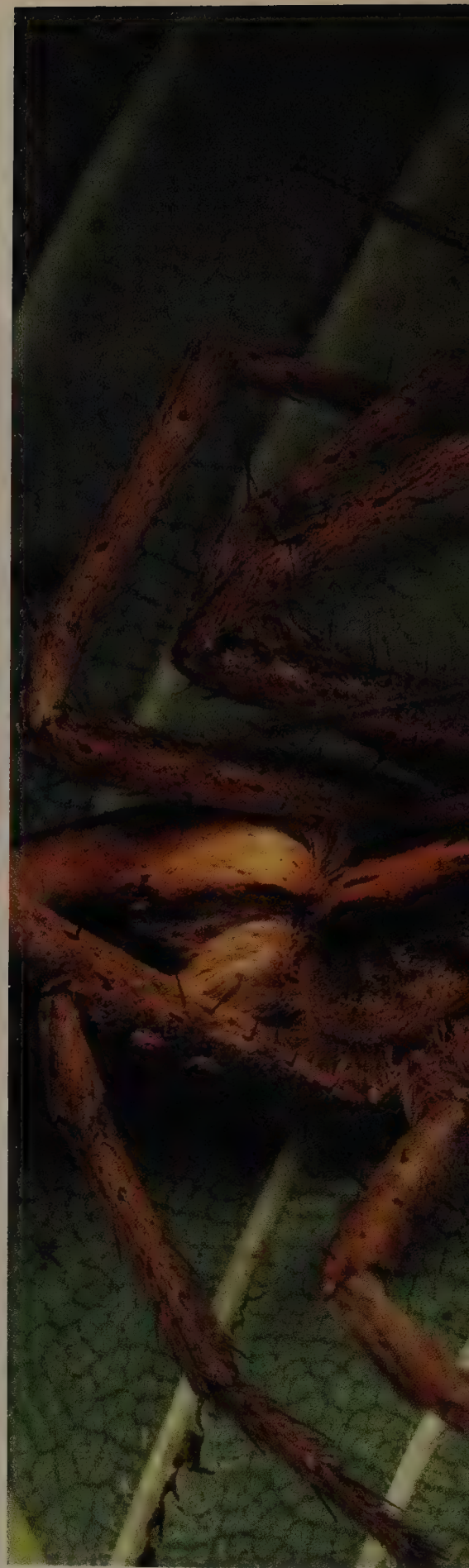
position, briefly bites the prey, then pivots in the opposite direction to fertilize the female's second genital opening with his other pedipalp—a process that takes another hour. The male bites into the prey one last time—an act that often precipitates a furious struggle for its possession. If he succeeds in wresting it from the female, he may rewrap it and use it again.

The quality and quantity of silk that the male produces are pivotal to the outcome of these sexual encounters. A nuptial gift can be made larger and more enticing if wound in many layers of silk; even a smallish insect becomes acceptable if suitably wrapped. This is not quite the deception that it appears, however, for spider silk is high in protein, and females consume the wrapping as eagerly as they do the gift. Furthermore, the silk is costly

for the fasting male to produce because it uses up precious calories.

The silk serves another important function: during copulation, the male's only hold on the nuptial gift is a tether of silk attached to his spinnerets. Because a female will often try to make off with the gift before the male has completed transferring his sperm or sometimes without mating at all, the strength of the silk line is vital in holding on to the insect—and his mate. Even very large prey are substantially wrapped to protect against theft by larcenous females.

By mating only with those males that can provide large insects and that can prevent her from stealing them, the female insures that her offspring will share the genes of males with beneficial attributes. But the female benefits from the nuptial gift in several other ways. Its





The male (left) holds his vibrating pedipalps high while the female bites into the wrapped insect, using her pedipalps to assess its size.



inside it, and guards it with her life. This care is essential; when we removed some females from their guard duty, spiders of other species quickly moved in and devoured the young.

Parasitic ichneumonid wasps are another threat. They can pierce the spider's egg sac and place a single egg of their own inside. The egg quickly hatches, and the wasp larva eats all the spider eggs before pupating, leaving the unknowing female spider fiercely guarding a young wasp. The rate of this parasitism rises from zero to more than 40 percent of the egg sacs as the summer progresses. Mating early in the season is therefore vital. But so are a few good meals. Well-fed females tend to produce eggs earlier and the eggs develop several weeks faster, reducing the likelihood that the clutch will fall prey to wasps. □

size undoubtedly has a bearing on how many eggs she can lay. (We have found that *P. mirabilis* fed one housefly per day produce nearly twice as many eggs as those given one fly every three days.) And since the nuptial gift is one of the last meals a female will have, its size also determines whether she will survive long enough to protect her offspring until they molt and disperse to hunt on their own. After laying her eggs, she will not eat again. The single batch of eggs is her lifetime reproductive effort, and her devotion to protecting the egg sac is total—leaving no time for hunting. For several weeks, she carries the egg sac in her jaws and immures herself within a silken cocoon, leaving only to warm her eggs in the sun. Then shortly before the spiderlings emerge, she constructs a tentlike nursery web, suspends the egg sac



Using the shiny, bean-shaped sac at the end of one pedipalp, the male transfers his sperm to the female, who is busy feasting on the prey.

A female carries an egg sac in her jaws for about three weeks before building a nursery web.



THE
COLD
FACTS
OF
WINTER

by James C. Halfpenny
Photographs by Michael S. Quinton

*For animals spending the winter in and around
Yellowstone, calorie counting is a matter
of life and death*



Yellowstone's mice and voles protect themselves from the cold by living in tunnels under the snowpack, but occasionally they may visit aboveground shelters, such as this marsh wren's nest, right. Thanks to their big size and bulk, moose, below, can produce more heat than they need to keep warm, even on breezy winter days.



It was the winter of 1978, the coldest on record in North America. One night in January, temperatures at my camp on the Lewis River in Yellowstone National Park fell to -54°F , the tenth night in a row the thermometer had dropped below the -40°F mark, and saucer-sized hoarfrost crystals lined the river's edge.

The next morning, as I welcomed the first rays of sunlight, a coyote pranced into view, paused, listened, and then pounced, sticking its nose beneath the snow in pursuit of a vole. About half a mile away, an elk plowed through the chest-deep snow, browsing on lodgepole pine needles. An increasing sensation of cold in my toes reminded me to wiggle them as a protection against frostbite, for at such low temperatures, energy—in the form of heat—is quickly drawn out of the body.

Energy, or perhaps more accurately, coping with the lack of it, is the key to winter survival. Winter itself is the result of a loss of energy: as the earth moves around the sun, the tilt of its axis causes the Northern Hemisphere to slant away from the sun during the winter months. Every sunbeam of incoming radiation must cover a larger area in winter, which results in a significant reduction in the amount of energy (measured in Calories, or Cal) per given unit of area. Each day in



A coyote, left, feeds on a dead elk. Omnivorous scavengers, coyotes make carrion a big part of their diet in winter, but they also dive through snow after rodents and race along hard snow crust in pursuit of larger prey. Below: To rest, coyotes curl up in soft snow, preferably where there is protection from the wind.



December, for example, every square inch of the Yellowstone area receives an average of 4.080 Cal of solar radiation, while energy lost from the earth's surface averages 4.118 Cal per square inch, producing a net loss of 0.038 Cal. (In June, by contrast, every square inch receives 1.850 Cal more than it loses.)

The most obvious and striking results of Yellowstone's winter energy deficit are the polar air masses that pour in from the north and the snow that often covers the region for six months or more. For the animals of Yellowstone, the margin for survival in the long winter is often narrow, and a few calories may be the difference between death and sprawling in the green grass of spring. Since 1970, I've studied the progression of winter in the Greater Yellowstone Ecosystem, watching those animals that make it and those that don't. (The Greater Yellowstone Ecosystem includes Grand Teton and Yellowstone national parks and all the national forests surrounding them.)

Faced with dramatic energy loss each fall, animals generally resort to one of three basic strategies: they may migrate, hibernate, or face the cold and snow head-on. Those that leave for the south, such as white pelicans and most of the region's great blue herons, do so by about October.

The great blues are gone for only a few months, some returning by February to look for nests. Other animals migrate to lower elevations. By November, great herds of elk—often single-file processions led by an old cow—wend their way down from summer meadows in search of a winter range where only a thin blanket of snow covers the grass from the summer growing season. Many creatures—such as reptiles, jumping mice, marmots, and bears—hibernate, disappearing usually until spring.

Those animals that remain active must contend with what may be the coldest, harshest winter conditions in the contiguous United States. The Yellowstone plateau is perched high in the central Rocky Mountains and surrounded by lofty mountain peaks. Official U. S. Weather Bureau records for Montana and Wyoming list record lows of -70° and -63° F, respectively. Unofficially, temperatures on the landlocked plateau drop much lower, and cold snaps often last for weeks. Snowfalls, which begin in September, add up to an average of 600 inches per winter and may last into June.

Preparations for winter are critical. Many species store food. I have watched nonhibernating pikas (rock "rabbits" of the alpine boulder fields) and pocket go-

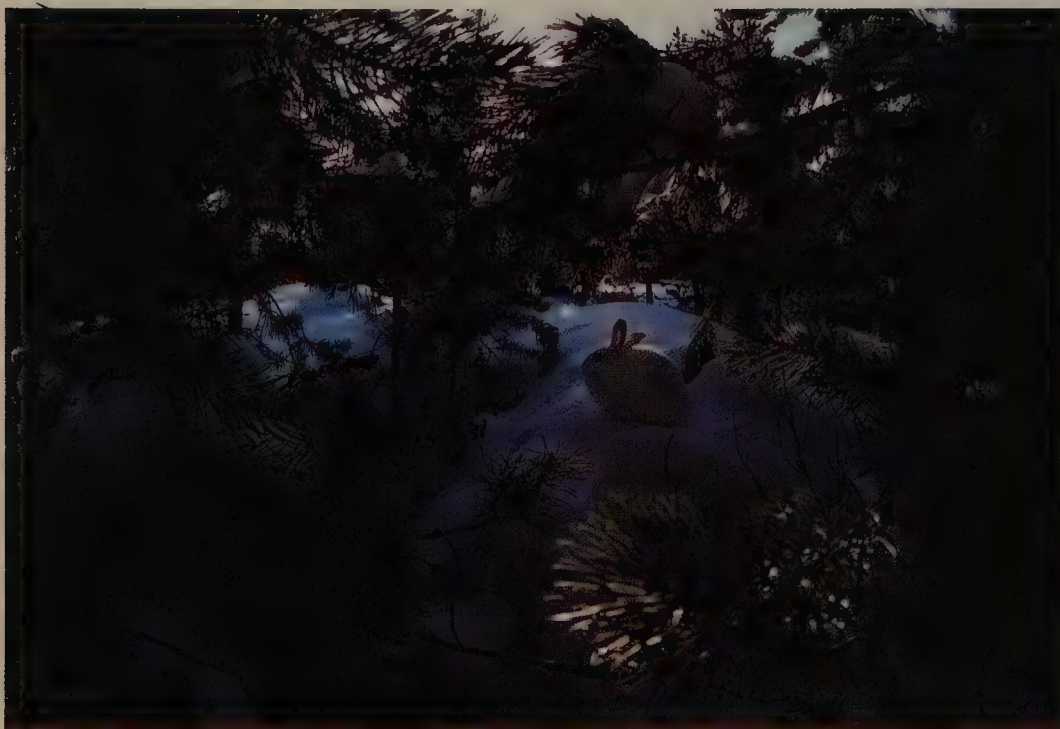
phers making bushelbasket-sized caches of greens and roots, respectively. The pikas store their hay above ground in boulder fields; gophers cache their supplies below ground and in the snowpack. Many animals add body fat: black bears put on as much as four inches of fat prior to hibernation. Other types of physical changes are also common. Following coyote tracks, I can tell when additional hair begins to grow on the animals' feet, to reduce heat loss via conduction to winter snows. All species molt to their thicker winter coats; even chickadees add more feathers. Some change color: weasels, for example, molt to white, becoming winter ermines.

The timing of color change is crucial. Normally, the snowshoe hare's internal clock coincides with the coming of snow, and its white phase hides it from all but the sharpest eyes. But when snow has been late in coming, I have seen the white hares sharply outlined against brown autumn vegetation, sitting ducks for raptors.

The snow, or nivean, environment provides two dramatically different situations for active, wintering wildlife: above and below the snowpack. Like all of the region's large mammals, moose must make a go of it above. To estimate the energy budgets of these 900-pound animals, Warren Porter of the University of Wisconsin, physician Roy Ozanne, graduate student Steve Beaupre, and I measured solar radiation, temperature, and wind speeds in different environmental settings. Next we calculated how much energy a moose would lose or gain in various situations. (The most familiar form of energy loss is heat transfer.) The computer model we came up with led us to conclude that even on a breezy winter afternoon, a moose produces more heat than it needs to keep warm. Indeed, during the warmest part of a winter day, we often find moose on shaded, north-facing slopes trying not to overheat. On the same day, elk, with a smaller body mass and less insulation, bask in the sun on south-facing slopes.

At night, the energy budget of a moose does go into the "red." Being out in an open meadow on a calm night at 23° F is energetically expensive, costing the moose

A snowshoe hare may enhance the camouflage effect of its white winter fur by sitting absolutely still. If necessary, however, it will dash away across the snow, springing on its outsize hind feet.



about 4.55 Cal of energy per hour—the equivalent of 1.6 Snickers bars per hour. By moving at night from the open meadow into the coniferous forest, where radiant energy from the trees and lower wind speed help keep it warm, the moose can cut its heat loss by more than one-third.

When the cover of the forest is not enough to stave off the cold, some large mammals take advantage of Yellowstone's abundant sources of geothermal energy. Through steam fumaroles, mud pots, and geysers, heat from the interior of the earth reaches the surface. Elk and bison often wallow on the snow-free ground created by thermal activity and bask in steam from hot pools or geysers.

Saunas may help take the edge off the cold sometimes, but life during the winter for Yellowstone's herbivores is always a race with starvation. Calories stored as fat during the summer must last all winter, when little food is available and what is found by pawing through the snow is of low quality. Carbohydrate- and protein-rich grasses from the summer transport their nutrients below ground in the winter, leaving behind only the dried, hard cellulose stalk for elk to feed on. As Norm Bishop, the research interpreter for Yellowstone National Park, says, "It's as if your annual budget of food consisted of a

box of cereal. During the summer you fatten up by eating all the cereal; during the winter all that is left to eat is the box."

Moose and elk face other problems during the winter. They themselves are a source of food not only for predators but also for parasites. Winter ticks feast on them. Skiing on backcountry trails in March, I often find moose beds stained red with blood from engorged ticks smashed when a moose rolled over. Large tufts of hair lying in the bed attest to the irritation caused by tick activity. Elk must deal with mange mites. These small relatives of spiders feed on the skin surface and cause hair loss, mostly in mature bulls. Massive amounts of hair may fall out, leaving nearly bald elk without their insulating fur coat. Weakened by anemia and the loss of blood and hair, many moose and elk simply do not have the energy reserves to survive.

Predators and scavengers benefit from the misfortunes of others. An old bull elk has few fat reserves left after maintaining a harem for breeding during the fall. Too weak to plow through the snow, he may slowly starve to death, or a mountain lion, a grizzly bear, or coyotes may come along to speed things up. Coyotes in Yellowstone often hunt in packs. I once watched three coyotes kill an elk calf while its



mother tried to protect it. One coyote would attack, drawing the attention of the mother, which would chase it off, while a second coyote would rush in and bite the calf. Eventually the calf died and was dragged off by the coyotes. As a pack, coyotes can protect their food from such formidable adversaries as mountain lions.

Even for coyotes, though, getting along in winter is not an easy trick. During the winter, a coyote must often travel long distances to find food, whether carrion or some small mammal holed up beneath the snow. The coyote's demise can be the snow surface. Unlike the moose, which can use its great bulk and long legs to plow

As streams freeze over, fish become prizes worth fighting for. This bald eagle has a cutthroat trout firmly in its grasp, but the hungry raven cannot pass up the possibility, however remote, of a fish dinner.



through snow up to three feet deep, the coyote must learn to negotiate the different types of snow. Coyotes detect surface changes in the snow through their feet. Tracking them on skis, I can tell from their footprints that they walk carefully on soft snow (trying to avoid sinking in too deep), trot on medium snow (but lightly, to avoid breaking through thin crusts), and lope on hard snow crusts. Coyotes often follow wind-packed courses on the leeward side of exposed sagebrush, avoiding careless steps to the side where the snow is soft. When the crust is hard enough, they can sometimes travel fast enough to outrun prey.

Patches of snow too soft for traveling may make a good bed, the coyote curling up to be gently covered by a blanket of blowing snow. The coyote's tactile sensitivity also enables it to know when it is safe to dive headfirst into the snow after a vole and when the snow is too hard.

Following the trail of a coyote can be an interesting lesson in energy conservation and, sometimes, humility. One winter night, as I sat gazing across the frozen expanse of Yellowstone Lake, a coyote loped into view on the lake ice. I squeaked like a mouse, and from a half mile out the coyote turned and approached me. Perhaps 100 feet away, it realized something

was not right, turned, and trotted off in the direction of my camp. Returning to camp, I discovered my pots gone from beside my tent. In the moonlight, I located coyote tracks and followed them a quarter mile onto the ice. There were the pots in a pile.

As I cooked breakfast the next morning, the full intent of the coyote's prank became apparent. A strong, acrid odor signaled the melting of coyote urine in my oatmeal pot. The coyote had scent marked my pots, telling me that this was its territory and that it didn't appreciate my trick.

Traveling through Yellowstone, I have noted two animals that seem to thrive on winter: river otters and dippers. As much of a cliché as it may seem, for otters, wintertime is playtime. Riverbanks near their dens are covered with slides, and I have watched them repeatedly climb banks seemingly just for the pleasure of sliding right back down. Where thermal activity along the shore of Yellowstone Lake opens up pools, otters will toboggan on the flat ice surface to open water a mile away.

Dippers, or water ouzels, are short-tailed, dark gray birds that live along stream edges year round. Even at -40°F , they wade into rushing streams and, while completely submerged, search for aquatic insects and small fish. At first the idea of these little birds engaging in polar-bear-club dips at subfreezing temperatures bothered me. Wouldn't these dips be energetically costly? Shouldn't a wet bird lose heat rapidly? When the air temperature is -40°F , however, the water is actually seventy-two degrees warmer than the air. Back at the surface, water is quickly shed from the feathers before it can freeze, thanks to a large waterproofing preen, or oil, gland.

As long as open water can be found, neither otters nor dippers seem to suffer from the food shortages that confront other Yellowstone inhabitants. Fish and aquatic insects are always abundant and probably slower moving—thus easier to catch—because of the colder water temperatures. During very cold winters, when the upper reaches of Yellowstone's streams freeze, both otters and dippers move to open water downstream.



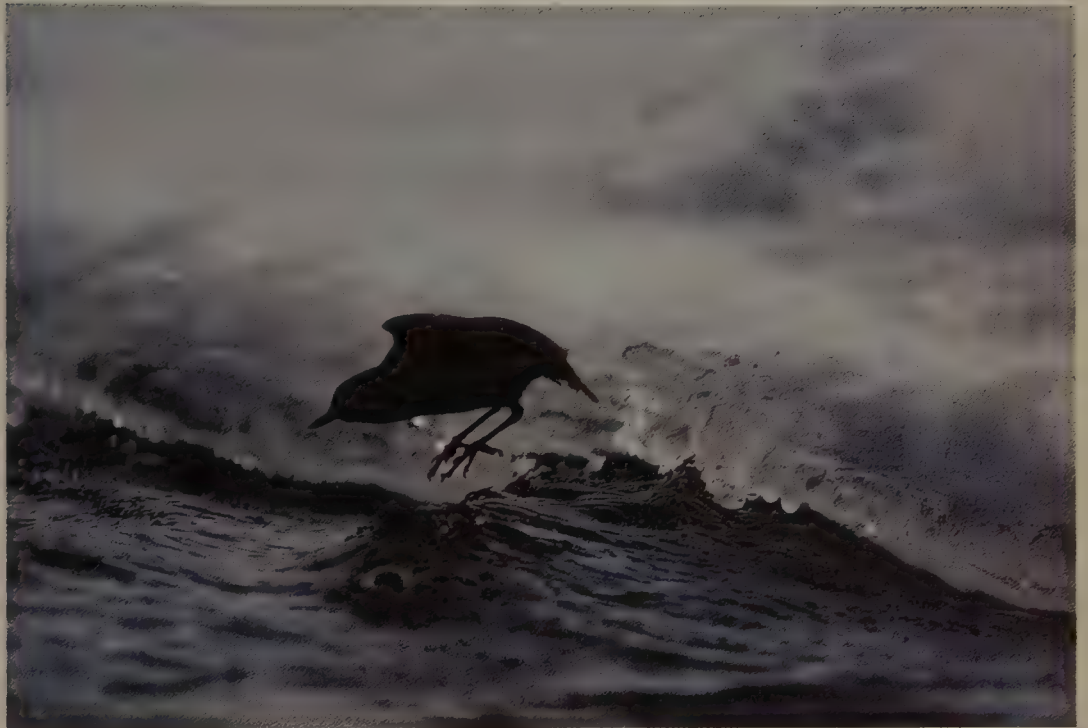
Below the snow there is a different world. Snow is a remarkable material, providing insulation and support for winter housing. For the small mammals of this subnivean realm, however, the timing of the first snowfall each autumn is critical. If cold polar fronts arrive before a protective mantle of snow is on the ground, plants and animals freeze. In years of late snowfalls, many of the tagged mice in our

study plots die. But once the first eight to ten inches of snow have built up, the daily fluctuations in air temperature do not reach beneath the snowpack, and temperatures below the snow remain fairly constant, within a few degrees of freezing.

With a snowpack deep enough to provide thermal stability, mice and voles reduce the number of daily trips to the snow surface. Often, I will go for days without

seeing a single track. Instead, the animals create a labyrinth of snow tunnels in which they travel around looking for dried grass, seeds, and the occasional insect. The tunnels provide a relatively warm haven from the cold at the surface: our calculations suggest that on a calm, 23° F night, a mouse would lose 3.7 times more energy per minute on the snow surface than it would in its tunnel.

Both river otters, left, and dippers, below, seem to thrive during winter in Yellowstone, as long as open water—and the fish and insects that live in it—can be found.



nest, mice wait out the worst winter weather.

Early naturalists noted tunnel entrances at the surface of the snow, especially as spring approached. They postulated that tunnels provided an outlet for the high concentrations of carbon dioxide that build up beneath the snowpack and also allowed the animals to emerge periodically to check for signs of spring. Because of the carbon dioxide theory, these tunnels became known as ventilator shafts.

I, too, observed ventilator shafts, but with some differences. In the Yellowstone area, shafts appeared mainly in January and February and especially after clear nights with very cold, subzero temperatures. By tracking, we discovered that, for unknown reasons, mice and voles not only venture above the snowpack on cold nights but also travel up to a quarter mile in open meadows. Following mouse trails and digging out the shafts, we found that most shafts descended only an inch or two beneath the surface and then leveled off and went about three inches horizontally before returning to the surface. In cross section, a shaft formed a roughly horse-shoe-shaped tunnel. At the bottom of each tunnel were often three or four pieces of scat, indicating that the animals had rested there for a few minutes.

We hypothesized that because of its large surface area in proportion to its small body, a mouse traveling in open meadows radiates a large percentage of its body heat to the clear night sky. When the mouse begins to get dangerously cold, it quickly burrows into the snow, which, although cold, radiates some energy to the mouse. In its warming hut, the mouse regains enough energy to resume its trip. On a particularly cold night, a mouse might dig several warming huts before successfully crossing a meadow.

Steve Beaupre, Roy Ozanne, and I tested the hypothesis by implanting a radio-transmitting thermometer into a deer mouse. At 3:00 A.M. on one January morning with the temperature about -30°F , we released the mouse back onto the snow. It began jumping swiftly across the snow surface. After a few minutes, our radio signal indicated that its internal body temperature (normally about 99°F) was dropping. The mouse quickly dug a warming hut, where it waited with the tip of its tail still visible. Twenty minutes later, rewarmed, it was again ready to venture out. We observed this behavior three times; each time the mouse's internal temperature dropped by as much as twenty degrees before returning to normal.

Other tunnels that go up to the surface

The tunnels are dark most of the winter, as accumulated snow more than three feet deep filters out all of the sun's rays. At the end of dark tunnels, mice construct grass nests where many huddle for warmth. The aggressive behavior typical of these small rodents during the summer quickly breaks down during the cold winter, when I have even found two different species of mice together in the same nest. Cuddled in their

Opportunistic hunters of the waterways, minks catch everything from crayfish to muskrats and ducks. Large prey, such as this mallard, may be carried back to one of the mink's dens and eaten later.

do exist. Researchers have recently documented the long-postulated pockets of carbon dioxide beneath the snow, perhaps caused by decomposing plant material. The new evidence supports the notion that some tunnels may serve as ventilator shafts. Such tunnels, however, have definite disadvantages: given an opening, long and lean members of the weasel family can also navigate the labyrinth.

Ermiones perhaps take advantage of these passages most frequently. But martens, normally considered to be surface and tree predators, may also use the tunnels. In 1986, Christie Shultz and I discovered the tracks of a marten leading from lodgepole pines to a small, frozen, snow-covered pond. Marten tracks around the edge of the pond led to thirty-eight holes. After excavating many yards of snow, we located muskrat tunnels around the pond. We also discovered partly eaten remains of five muskrats, indicating that the marten had had a successful hunt.

One April, perched on my pack on a frozen stream bed, I watched a blue heron fly to its nest. Suddenly, I heard familiar creaking, rumbling, and cracking sounds. Jumping to my feet, I grabbed my pack and skied up the bank just in time to watch the stream channel turn sky blue and the snow and ice become saturated with water. Within minutes, the ice began to break up and flow downstream.

Watching spring return to Yellowstone is still thrilling, even after all these years. With every passing day, more and more energy pours back into Yellowstone. On south-facing slopes, where the snow has already melted, cow elk, round with soon-to-be-born calves, feed. Soon sow grizzlies will emerge with their young, born during the long winter's sleep. The calls of pikas signal their return to the surface, and marmot tracks tell of their awakening from hibernation. If a heavy late snow doesn't catch them off guard, all these animals—newborns and survivors—can look forward to several months of a gentler, lush Yellowstone. Many will soon be dedicating their energies to courtship, mating, and rearing young. As for me, my energy will be spent counting the weeks until the next winter season. □





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SCIENCE LITE

How to Bear Gifts

I told you I needed black socks

by Roger L. Welsch

I knew that I had been accepted into the Omaha Indian community the evening I was with some Omaha friends and the topic of conversation was why white people smell funny. (The conclusion was that stinky stuff gets stuck in all those body hairs.) On such occasions I learn a lot about Omaha culture, but more importantly, I learn about my own white, mainstream, lower-middle-class culture. The Omahas never ask me for explanations of why my people do the things they do, and I'm glad they don't, because I don't have many answers.

The Omahas talk about white people's preoccupation with time and money, inability to sense even the most obvious workings of the gods, difficulty in conducting meaningful conversations (even within their own families), and lack of understanding about... well, about almost everything. They aren't angry or bitter or cynical or mocking; they just can't figure white people out.

About this time of year, the Omahas talk a lot about the mainstream's system of giving, especially the custom of "exchanging" gifts. Actually, they don't so much talk about it as shake their heads in incomprehension over the calculated reciprocity involved. The Omahas give gifts and conduct trade, but they never confuse the two. If an Omaha gives a gift worth thirty dollars or so (a blanket, for example), the recipient has to be careful not to give that person something worth thirty dollars anytime soon. Otherwise he risks giving the impression of turning the gift into a purchase.

The amount of time that must be allowed to pass is a subjective determination but depends roughly on the value of the gift—maybe three or four months for a blanket. A fifty-dollar saddle requires longer to fade from community memory,

perhaps a half year. A cow takes forever. Since gift giving is an important part of Omaha culture—the means by which one acquires prestige and status within the community—mental computing and accounting consume a lot of Omaha tribal energy.

The mainstream's concentration is the opposite: "Last year was the third year in a row your cheapskate cousin in Des Moines didn't send us a card, and this year she is off the list!" Imagine being a part of a society in which you avoid equity while living in the midst of a culture that insists on it!

Or consider the common mainstream family practice of "deciding what we'll spend this year": "Okay, this Christmas we'll give Mom and Dad gifts worth no more than \$25, brothers and sisters items worth no more than \$15, nieces and nephews \$5.50, aunts and uncles \$17.76, pets \$3.36, except goldfish, for which gifts will not exceed \$2, not including sales tax." (In a pre-Christmas family briefing—fresh, I suspect, from an Indian gathering—I once rashly suggested that we give whatever gifts we considered appropriate. I'm no longer a part of that family.)

As if that were not enough, the Omahas consider it more blessed to give than receive. (Lord only knows where they got that idea.) And that includes giving what has already been given, perhaps the source of the idiom "Indian giver." Among the Omahas, food is a particularly respectful gift, so once, when I wanted to do something nice for an Omaha friend, I put together a big basket of fresh fruit, sausages, cheese, lots of yummys. I gave the basket to my friend at a public gathering of the Omaha Indian community.

We mainstreamers consider wealth and acquisition to be important, so we make wealth and acquisition public—big cars,

swimming pools, silk suits, nose bobs, right out there where everyone can see them. Because the Omahas consider giving to be important, they make it public. Gifts are given at powwows, prayer meetings, hand games, gourd dances, wherever there's a crowd. And they are announced by a crier, who loudly proclaims and compliments their value and importance.

So I gave my friend the basket of food through the crier, who announced the gift amid a hubbub of approval. My friend came forward with tears in his eyes and accepted my gift. He embraced me and called me "cousin." But before I even had time to turn from the crier and return to my seat, my friend stepped to someone else in the room—someone I scarcely knew—and gave her the basket I had put such effort into. Well, great. My gift apparently meant no more to my friend than an extra set of shoelaces.

Later I found out that the standard monologue in our society—"Oh, my goodness, what a wonderful rhinestone aspirin locket! I've been wanting one for so long! I'm going to wear this to church tomorrow... no, I won't! I'm going to save this for special occasions like meeting the queen; and I'll call my lawyer next week to be sure that when I die it goes to my oldest granddaughter for her dowry"—is a mystery within a culture where giving, not having, is important. The Omaha formula in the same situation would be, "This is such a wonderful gift, I would be proud to give it away myself. In fact, I think I will. Here and now." I have seen gifts so important that they were given away three times on the same occasion.

It gets worse—or better, depending on how willing you are to pursue Omaha logic. When I was given my Omaha name in 1967, I knew it was proper for me to put together a feast and give gifts, so I asked

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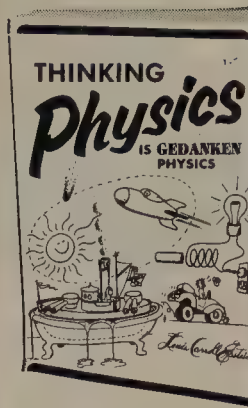


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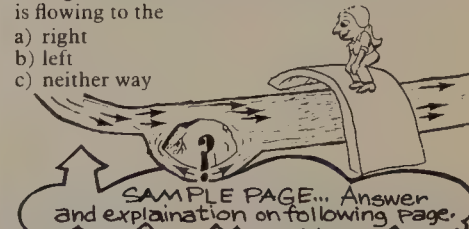
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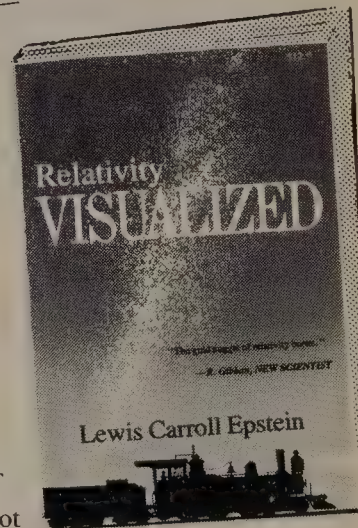
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an old friend, "How much food should I prepare? How many gifts should I bring?" I knew there would be four or five hundred people at the gathering, so I was prepared for a jolt, but not quite for the one I got.

My friend said, "This is an important occasion for you."

"About the most important thing that has ever happened to me," I responded.

"Then spend everything you have."

"Uh, everything I have?"

"Everything."

I spent quite a bit, but Indian name or not, I didn't spend everything I had. There's still a lot of German blood in these veins.

Even before the Omaha Tribe wrenched my understanding of gift-giving protocol, my mother gave me reason to wonder. Every year in mid-September she asks for a list of what my wife, daughter, and I want for Christmas. We give her the list and then she gets us something else.

"Mom," I say annually, staring with bewilderment at a package of a dozen of those undershirts with little, thin straps that go over your shoulders and which I never wear, "I told you I needed black socks."

"I won't buy you any more black socks."

"But I need black socks."

"Christmas isn't a time for giving things we need."

"Then why did you give me undershirts with little, thin shoulder straps? I don't wear undershirts with little, thin shoulder straps."

"See? It's not something you need, and at Christmas you're not supposed to give things people need."

Part of the problem with the American system of gift giving may lie within the nature of our gifts. My son gives me presents he thinks will improve my mind, which is nice, but I can't help wondering why he thinks my mind needs improvement. I don't know where my wife gets her ideas for gifts. It's as if she's never met me. Last year she gave me a pair of boxing gloves. In all fairness, she maintains she is equally mystified by the fruit-drying oven I gave her.

I blamed the fruit-drying oven error on a high-pressure salesman. Charles Kuralt, as usual, says it best: "We call gift shops gift shops because they sell things we'd never buy for ourselves."

No one can recall how it started, but my father and I have a good arrangement for Christmas gifts: we exchange screwdrivers. Family legend has it that the screwdriver tradition started when I was a little boy and about all I could think of by way of a Christmas gift for Dad, and all I could afford, was a screwdriver. Every year a screwdriver. When I became an adult, Dad returned the favor, and that's what we do every year now.



"Elaine and I were among the first people to come out against releasing fluorocarbons into the atmosphere."

Dad's gift is my favorite. I know it's a screwdriver but I never know what kind, and there are lots of kinds of screwdrivers. Besides, not a year passes during which I don't lose my Christmas screwdriver from Dad, so I am always in need of another, no matter what kind it is. (On the other hand, Dad never loses anything—so his basement is full of screwdrivers.)

The situation gets even more confusing if we turn our analysis of gift giving to children. The reality is that in the case of children, like that of the Omahas, the protocol of giving operates within another logic. Everyone sees the truth annually and comments on it: the boxes the gifts come in seem to be more fun for the children than the gifts. Why? Because the boxes are more fun than the gifts that come in them.

Even more fun than the gifts that come in the boxes or the boxes they come in are the gifts the other kid gets and the boxes they come in. (This insight has a much broader application than Christmas gifts and will eventually make someone rich. Market toys as "The Other Kid's Toys" and the money will roll in, trust me.)

Far be it from me, however, to point out the faults of the world without offering a clear plan for fixing them. All we have to do is mix everything together—Indian ideas, kid stuff, mothers' problems with buying socks, screwdrivers—and everything will work out fine.

Here's what I propose:

1. This year give your friends and relatives things they don't want or need—preferably things they already have and like or that you already have and like.
2. Ignore your family's agreement about spending limits.
3. Give presents to the wrong people and invite them to make exchanges on the spot, which means everyone will get two presents instead of one and will wind up with something they like. (I don't know how Linda feels about boxing gloves, but I sure could use the fruit-drying oven.)
4. Tell each recipient of a gift out loud, and publicly, how you arrived at your decision. If you can't imagine why you are giving what you're giving, it's a bad idea anyway. Maybe once your friends and family hear your explanation, they'll like your gifts.
5. Above all, put presents in interesting boxes. That'll make everyone happy.

Me, I'm giving everyone indoor mushroom gardens this year. Don't ask me why.

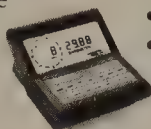
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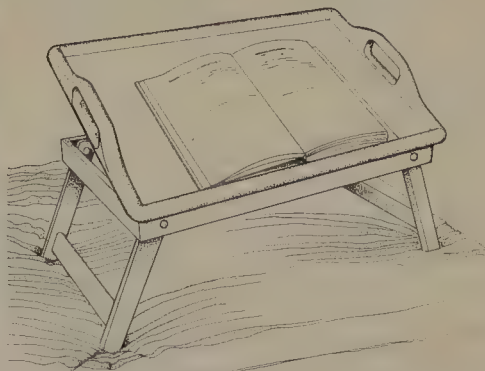
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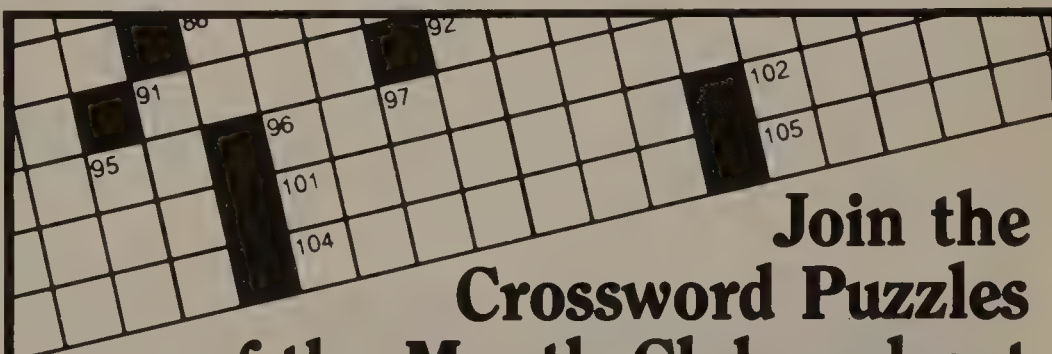
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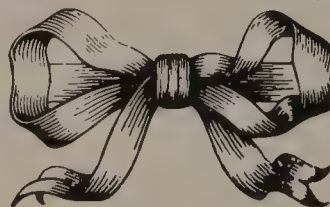
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AT THE AMERICAN MUSEUM

ORIGAMI HOLIDAY TREE

This season's Origami Holiday Tree will be on display in the Roosevelt Memorial Hall of the American Museum from November 25 through January 1.

To add a flush of Christmas red to the nineteen-foot tree, hundreds of paper strawberries will hang among the thousand or so origami representations of animals, ranging from antelopes to zebras, apatosauruses to dimetrodons, grasshoppers to honeybees, angelfish to sharks. More than 2,000 silver stars, cantilevered from the branches on wires, provide the tree with a glittering halo.

An annual tradition since 1972, the Museum's tree was the first of its kind on public display. Its decorations are an all-volunteer effort, and teachers will be on hand to show visitors how to fold their own origami ornaments.

KWANZAA

Three days of programs will mark the Museum's celebration of Kwanzaa, Swahili for "first fruits of the harvest." During the week of December 26 to January 1, each day of this African American holiday is dedicated to one of seven principles: *umoya* (unity), *kujichagulia* (self-determination), *ujima* (collective work and responsibility), *ujamaa* (economic cooperation), *nia* (purpose), *kuumba* (creativity), and *imani* (faith).

On Friday, December 27, the Museum will host an African marketplace in the Hall of Ocean Life from 11:00 A.M. to 6:00 P.M. Vendors will sell books, textiles,

jewelry, foods, and Kwanzaa crafts; cultural activities will also be featured. Theatrical presentations and participatory workshops will take place on Saturday and Sunday, December 28 and 29.

These programs are made possible by a gift to the Museum from the Samuel and May Rudin Foundation and by contributions from the New York Urban Coalition. For information or for a flier detailing these free events, call (212) 769-5315.

BIRDS IN ART, 1991

Sixty works, chosen from more than 1,000 entries, feature the best contemporary painting, printmaking, and sculpture depicting birds by artists worldwide. In this year's show, sculptor Larry Barth of Stahlstown, Pennsylvania, has been chosen Master Wildlife Artist, an honor that in past years has been given to Roger Tory Peterson, Don Richard Eckelberry, Peter Scott, Guy Coheleach, and Lars Jonsson. Organized annually since 1976 by the Leigh Yawkey Woodson Art Museum in Wausau, Wisconsin, the exhibition opens this year on Friday, December 6, and runs through Sunday, March 1, 1992, in Gallery 77.

MEMBERS' PROGRAMS

In 1934, Roger Tory Peterson published *The Field Guide to Birds*, beginning a long and distinguished career as an author and artist. Peterson will reflect on his experiences discovering and studying birds all over the world on Wednesday, December 4, at 8:00 P.M. in the Main Au-

ditorium. Tickets are \$12 (\$8 for members). Call (212) 769-5606 for ticket availability.

Folk artist Richie Havens will make a special appearance at the Museum on Thursday, December 19, at 7:00 P.M. in the Main Auditorium. Since his first album in 1967 and his performance at the 1969 Woodstock Festival, Havens, whose most recent album is *Now*, has contributed regularly to the music world. Tickets are \$20 (\$12 for members). Call (212) 769-5606 for ticket availability.

NATIVE AMERICAN CELEBRATION

Dance programs, lectures, and demonstrations of mask carving will be presented in conjunction with the special exhibition "Chiefly Feasts: The Enduring Kwakiutl Potlatch," which will run through February 23, 1992. For additional information call (212) 769-5305.

The Leonhardt People Center celebrates Native American culture with free weekend programs this month. On Saturday and Sunday, December 14 and 15, Tchin, a Blackfoot and Narragansett Indian, will talk on "Growing up Native American"; Cherokee Jeff Kalin will demonstrate precontact stone tool technology; and Snowflower and Star, Blackfoot and Narragansett Indians, will tell stories through dance.

The People Center will be closed on December 21 and 22. For a full schedule of events, call (212) 769-5182.

CHRISTMAS AT THE PLANETARIUM

Was it a star, a comet, or a meteor that led the Wise Men to Bethlehem? Scientists, theologians, and historians have all contributed to the search for answers. Beginning Wednesday, November 27, visitors to the Planetarium can travel back nearly 2,000 years in time to explore the skies of the first Christmas.

On Monday and Tuesday, December 16 and 17, in the Sky Theater, the Planetarium's annual holiday concert will feature the Ensemble for Early Music, which will play selections from the Middle Ages. Performances start at 7:30 P.M., and tickets are \$15 (\$12 for members). For more information, call (212) 769-5900.

These events take place at the American Museum of Natural History, located on Central Park West at 79th Street in New York City. The Kaufmann and Linder theaters and the Leonhardt People Center are located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.



The Pink Slipper, by John Felsing, is one of sixty works featured in the "Birds in Art" exhibition.

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Luck of the Draw

by Neil H. Landman

Why do some species survive and persist for tens of millions of years while others disappear? What is the secret of species longevity? Do some biological traits favor survival and others invite extinction? Geologist Peter Ward has been at work all over the world investigating these questions among fossils both living and dead. *On Methuselah's Trail* is an apt title for this quest. Methuselah, the grandfather of Noah, was a biblical patriarch who was believed to have lived 969 years. Indeed, the survival of very ancient organisms to the present, so-called living fossils, reveals a persistence of mythical proportions. Equally impressive is the evolutionary drama of life on earth in which these living fossils play a role.

Some living fossils—such as the horse-tail plant from the Carboniferous period or the inarticulate brachiopod *Lingula* from the Cambrian period—are species that have remained unchanged for tens or even hundreds of millions of years. Others such as the coelacanth, a fish from the Comoro Islands in the Indian Ocean, belong to new genera and species not recognizable in the fossil record but are the sole survivors of ancient lineages.

An important dimension to Ward's unfolding fossil trail is the subject of mass extinctions, the large perturbations in the history of life when as much as 50 percent

of all life on earth disappeared. Two of the most important extinctions occurred at the end of the Permian (250 million years ago) and at the end of the Cretaceous (66 million years ago). They define the three major subdivisions in the history of life: the Paleozoic, Mesozoic, and Cenozoic eras. Still very much under debate, however, are the causes and consequences of these extinctions.

We follow Ward around the globe as he studies the record of extinctions and searches out living fossils. Along the way, we learn about general themes in the history of life, for example, the first appearance of multicellular animals and the rise of land plants. With Ward we dive into Puget Sound after brachiopods, which are

ON METHUSELAH'S TRAIL: LIVING FOSSILS AND THE GREAT EXTINCTIONS, by Peter Douglas Ward. *W. H. Freeman and Company*, \$18.95; 212 pp., illus.

rare today but were common in the Paleozoic. We trek into the Great Valley of California to uncover fossil ammonites; then we continue on to Zumaya, Spain, to investigate the record—preserved in a sequence of maroon-colored rock layers—of the extinction that ended the Mesozoic era. We observe horseshoe crabs along the shoreline in Woods Hole, Massachusetts, and we end up in Paris at the Museum of Paleontology examining fossil collections assembled more than a century ago.

These peregrinations are as much fun as they are informative. Floating in the crystal clear waters of Palau in the western Pacific, Ward watches from above as nautilus, surviving members of a group of shelled cephalopods, descend into deeper water.

They hang for a moment, still tightly closed in their shells, and then cautiously extend tentacles outward, testing the water...

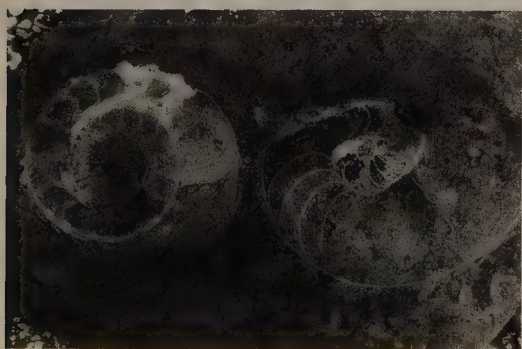
They extend fully and expel jets of water from their funnels. In a rush, they shoot downward, then descend in huge slow spirals... until they become small white crescents against the blackness below.

Or standing in a remote spot in the northeastern corner of Washington State, surrounded by rocks deposited before the advent of life, Ward helps us imagine the Precambrian world, more than a half billion years ago.

The greatest wonder... would have been the first glimpse of the moon, at that time perhaps twice as close to the earth as it is today. It appears as a giant planet rising, blinding white with its reflected sunlight, and moving across the sky much more quickly than it does today. I feel the land beneath my feet tremble slightly with the sway of a small earthquake, for minor tremors shake the earth as the passing moon stretches grasping gravitational fingers into the earth's crust.

Woven throughout many of these adventures is the question of the causes and consequences of the extinction that ended the Cretaceous period closing the Mesozoic era. This extinction wiped out dinosaurs on the land and various animals in the sea—notably microscopic plankton and certain shelled cephalopods. What caused it? Possibly a lowering of sea level over several million years (resulting in a reduction in habitable living area for marine creatures and a worldwide harshening of climate) or a meteor colliding with the earth, which may have left a telltale layer of iridium (an element generally absent from the earth's surface but common in meteors) embedded in rocks formed at that time. This collision would have generated a massive cloud of dust in the atmosphere, worldwide fires, total darkness for several months, and acidification of the surface waters of the world's oceans.

Whatever the exact nature of the envi-



Fossils of an ammonite and nautilus from the beach at Lyme Regis, England

Peter Douglas Ward

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ronmental deterioration or collapse, some species survived and others disappeared. The consequences were enormous, and the history of whole groups of organisms was irrevocably changed.

Ward devotes one-quarter of his book to a group of animals known as the externally shelled cephalopods in order to best illustrate the events at the end of the Cretaceous. This group represents Ward's major research interest and my own. The externally shelled cephalopods consisted of the ammonites and the nautilids and are especially instructive because they provide an example of differential survival within the same class. While the nautilids were more primitive, both groups were characterized by external shells subdivided into air chambers that provided the buoyancy necessary to counterbalance the weight of the growing shell. Today nautilids are represented by the modern nautilus. Ammonites no longer exist, although they may have shared many features with living squids and cuttlefish.

The ammonites first appeared about 400 million years ago. Ward describes their evolution as a progressive trend toward improved shell design to avoid fish predation, culminating in the appearance of the last ammonites, "the swiftest swimmers" or "forms that lived in the mid-water regions, relatively safe from the predators . . . below . . . and above." However, "near the end of their long reign," Ward writes,

the ammonites experimented with other shell shapes [other than flat spirals] under the selective pressure brought to bear by the merciless predators. But the extravagant diversity of form is a mark of desperation.

I would disagree slightly here and argue that the pattern of ammonite evolution was, in actuality, much more complex, resembling a lush bush rather than a single stem growing in one direction. Some ammonite branches were characterized by numerous species, each of which lived for a short time, whereas others, like the *Lytoceras*, had fewer but longer-lived species. Many of the last ammonites on earth belonged to this branch and were not the evolutionary end products of a progressive trend. What's more, the appearance of nonspiral ammonite shell shapes was not limited to the close of the Cretaceous, as Ward suggests, but happened several times in the history of the group.

The causes of ammonite evolution were also complex. Predation and the avoidance of predators were important factors, as Ward emphasizes, but so too were changes in sea level, which limited the area of shallow shelf inhabited by many

ammonites. Competition with fish and other marine organisms, as well as periodic episodes of low oxygen levels in the world's oceans, also affected ammonite diversity. In sum, I would claim that ammonite evolution was both complex and multicausal and did not show a uniform progression over time.

Like the ammonites, the nautilids also originated approximately 400 million years ago but belong to an older, larger group, known as the nautiloids, that dates back to the Cambrian period. The nautilids were characterized by few genera and species and never achieved the taxonomic diversity of the ammonites. As a member of this primitive group, today's nautilus is commonly referred to as a "living fossil," but all the extant species are probably less than 5 million years old. They live at depths of up to 2,000 feet in the Pacific and Indian oceans and swim just above the bottom, scavenging for food. Populations of some species migrate upward to the surface to feed, but only at night, presumably to avoid predators.

According to Ward, this avoidance of predators is indicative of the course of ammonite and nautilid history and explains the reduction in ammonite diversity toward the end of the Cretaceous. "As the new predators appeared on the scene during the Cretaceous Period," Ward writes, the shallow water nautilus and ammonites had to adapt or die. At first they tried to adapt: they built sturdier shells replete with spires and tubercles. But even the spiniest shells were being broken. There was only one escape for the ones that still lived, the same strategy used by the nautilus today: they retreated to the deep, where the eternal blackness can thwart the search of the hungriest visually oriented predator. But the deep exacts its own price: slow growth, little food. It's a draconian solution, and it put the chambered cephalopods in a no-win situation.

This scenario probably requires some revision. For example, despite a "no-win situation," the deep-sea niche of the nautilus has not compromised its survival. The nautilus is broadly distributed throughout the South Pacific, ranging from Australia in the west to Fiji in the east, a distance of several thousand miles. Some scientists even believe that the nautilus is currently undergoing an explosion of new species.

What's more, the habitat of today's nautilus is very different from that of many extinct nautilids. During the Late Cretaceous and well into the Cenozoic era that followed, for example, many nautilids continued to live in shallow waters in spite of the presence of shell-eating predators. On the other side of the coin, many ammonites lived in deep water for most of

the Mesozoic. They didn't all retreat there just at the end of the Cretaceous. Clearly, a number of factors, and not just those "merciless predators," must have contributed to the evolution of ammonites and their decrease in diversity toward the close of the Cretaceous.

Arguments of causation aside, however, how do the numbers of ammonites and nautilids compare at the end of the Mesozoic? The fossil record reveals that at that time there were about a dozen ammonite genera worldwide with at least as many species, whereas there were at most seven nautilid genera.

And now the \$10,000 question: Why did the less diverse nautilids survive and the more diverse ammonites disappear in the events that ended the Cretaceous period (see "Not to Be or to Be?" *Natural History*, August 1984)? There are at least two possible explanations, one broadly ecological and the other more specifically based. The first explanation rests on the inferred ecological differences between the two groups. (Ward would disagree, arguing that the two groups were "alike in morphology and probably ecology.") However, the nautilids, with their simple shells (like those of modern nautilus), were probably ecological generalists, tol-

erant of a variety of environmental conditions and foods. With more diverse shapes and feeding apparatuses, ammonites may have been specialists, relying on particular food sources and living in narrowly prescribed environments. Faced with deteriorating or catastrophic conditions at the end of the Cretaceous, the generalists survived while the specialists perished.

The second explanation, on which Ward and I agree, is based on a well-documented event at the end of the Cretaceous, the near annihilation of the calcareous marine plankton. These were tiny microorganisms that lived in the upper surface layers of the world's oceans. (Their destruction was, fortunately, not complete and they are still very much with us today.) How does this explain the differential survival of the nautilids versus the ammonites? The answer may lie in the different life histories of the two groups. An ammonite began life at a very small size; it hatched at less than 1/25 of an inch. Equipped with a buoyancy chamber, the tiny ammonite may have floated in the surface layers of plankton until it grew large enough to swim nearer the bottom or in midwaters, as its parents did.

A nautilid, on the other hand, hatched at more than ten times the size of an

ammonite. A newly hatched nautilid probably began swimming immediately and followed a mode of life similar to that of the adults. Like suspension-feeding bivalves and many other plankton-eating animals, the ammonites were inextricably caught up in the collapse of the marine plankton, whereas the nautilids escaped.

That the newly hatched young of ammonites may have spent some time in the plankton probably served this group perfectly well throughout its long evolutionary history. In particular, planktonic dispersal helped insure the widespread distribution of individuals within a population. However, in the environmental events that ended the Cretaceous, this feature of the ammonite life cycle became a liability.

Is there a message in all of this? Perhaps it is a reminder. Generally, we are inclined to believe that a species' survival depends on gaining the competitive edge. However, if this second explanation is correct, it is evident, as Ward also concludes at the end of his book, that luck, too, has a place.

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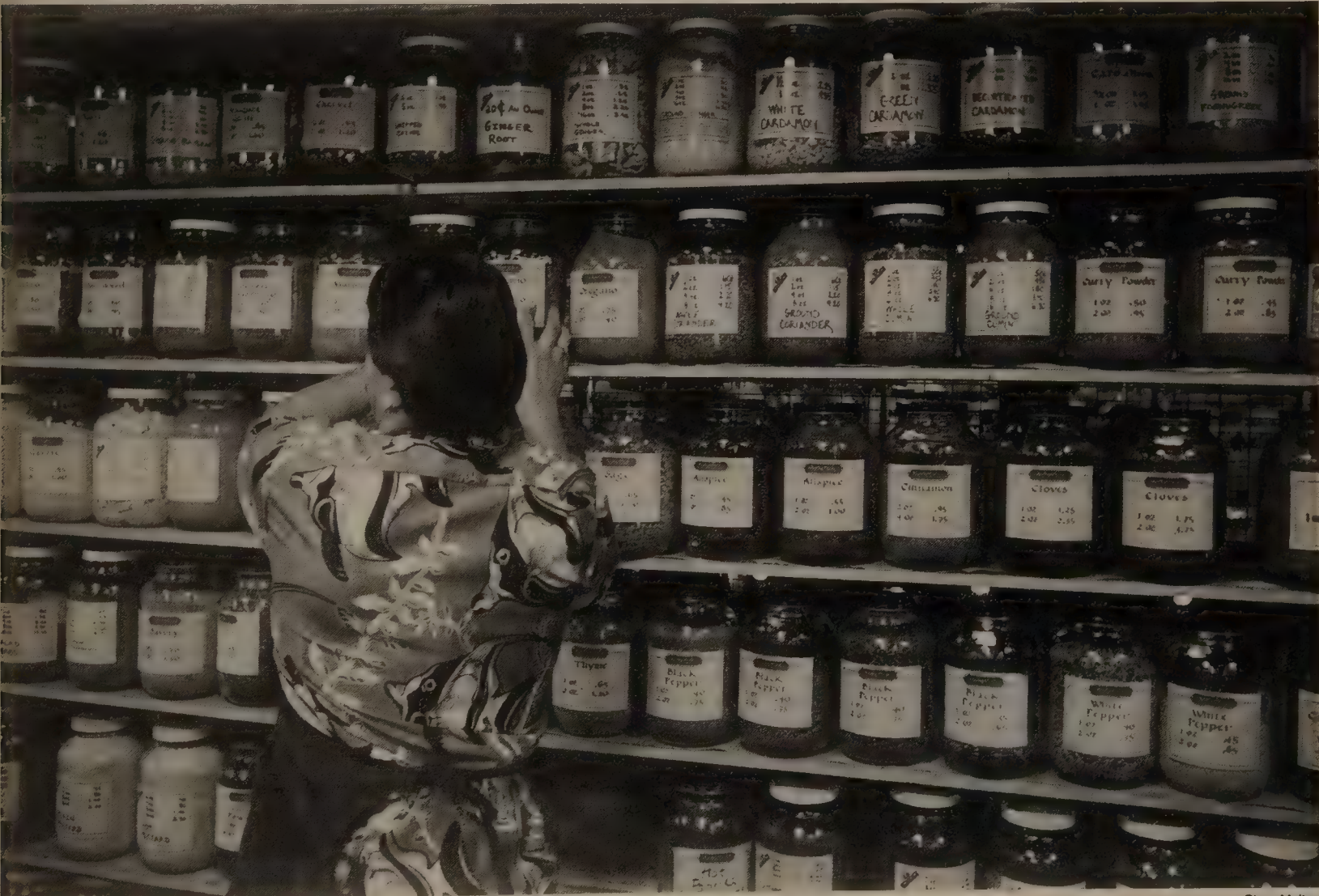
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Solar Celebration

by Gail S. Cleere

On December 22, at 3:54 A.M., EST, the sun takes its lowest, southernmost path across the sky. It rises and sets at its farthest points south of due east and west. The winter solstice, meaning the "sun stands still," is so named because the sun appears to linger in this position before moving north again. The earth's axis at the winter solstice tilts directly away from the sun, so that the Northern Hemisphere receives a minimum of sunlight. While the sun shines directly down on the Tropic of Capricorn in the Southern Hemisphere, the Northern Hemisphere gets only the weak, low-angle rays and the shortest day of the year.

Rarely do people poke their heads out of their windows and note the sun's position at sunrise or sunset and remark on its particular significance. But the winter solstice is different: it marks the end of the sun's southward creep in the heavens, and the days now start to lengthen. This day became the basis for a number of early celebrations and festivities, such as the Yule Girth festival of the Goths and Saxons, whose custom on the winter solstice was to kindle great outdoor fires to urge on the sun. Today, Christians still celebrate with light at this time of year. They burn yule logs and decorate evergreen trees and windows with Christmas lights.

The Christmas story tells of a mysterious star in the east—a line that has confounded astronomers for millennia. Assuming Matthew was not simply weaving a beautiful tale, the wise men who claimed to have seen this star would not have been simple desert nomads easily awed by the night sky phenomena but serious sky watchers—the astronomers and scholars of the day. Certainly, what they saw would not have been ordinary; it may have been a conjunction of bright planets, a

nova, or a comet (as portrayed by the Florentine painter Giotto in his painting *Adoration of the Magi*). Of course, all this speculation is moot if Matthew's story is considered miraculous.

This time of year is also the middle of the ancient Greek Halcyon days. In Greek mythology, King Ceyx of Thessaly and his wife Halcyone were changed by the gods into kingfishers, birds that were thought to breed about the time of the winter solstice, building their nests upon the sea in a period of extended calm and peace.

That the winter solstice, the ancient Greek Halcyon days, and the Christian Christmas come together so neatly at this time of year is somehow comforting. Happy holidays, and enjoy the view.

THE PLANETS IN DECEMBER

Mercury moves around the sun at a fast clip; it reaches inferior conjunction (between the earth and the sun) on the 8th and its greatest distance west of the sun on the 27th. During the latter half of the month, you'll be able to spot Mercury in the morning twilight low in the southeast, left of the ruddy star Antares.

Venus is brilliant in December at -4.2 magnitude, rising more than three hours before the sun all month. At sunrise, the planet is some thirty degrees above the southeastern horizon. On the 2d, the waning crescent moon and Venus form an attractive triangle with the star Spica.

Mars slides into the constellation Ophiuchus, the Serpent Bearer, whose lowermost part reaches down into the zodiac between Scorpius and Sagittarius. At month's end, just before sunup, you might spot the planet low in the southeast beneath Mercury if you have an unobstructed horizon. Mars and Mercury form a triangle with the ruddy star Antares.

Jupiter and **Saturn** are fine sights in December. Brilliant Jupiter, below the main stars of Leo, rises about midnight as December begins and some two hours earlier by New Year's Eve. The next planet in the solar system, Saturn, is still visible from about two and a half to four hours after sunset as a lone bright "star" in the southwest. Both Jupiter and Saturn—the former with its flanking satellites and cloud belts and the latter with its famous rings—are fine sights in that newly acquired Christmas telescope.

The **Moon** is new at 10:56 P.M., EST, on December 5th; at first quarter at 4:32 A.M., EST, on the 14th; full at 5:23 A.M., EST, on the 21st; and at last quarter at 8:55 P.M., EST, on the 27th. A partial eclipse takes place on the 21st; a sliver will be missing from the moon's bottom edge as it dips into the earth's umbra (dark shadow) between 5:00 and 6:06 A.M., EST. For about a half-hour before and after those times, the moon's lower portion (which will appear at lower left because of the moon's position in the northwest) will be in the earth's penumbra (partial shadow) and will appear somewhat smudgy.

The Geminid meteors, which could be the most spectacular shower of "shooting stars" of the year, peak on the night of December 13. These meteors (approximately fifty per hour) are possibly remnants of an extinct comet, whose core is now the asteroid Phaethon. The shower will be best in the hours after midnight when the moon sets.

Gail S. Cleere writes on popular astronomy and is a founding member of the International Dark Sky Association, an organization dedicated to preserving the skies for astronomy.

Report from Oxford

From the popularity of McDonald's hamburgers to the pre-Turkish origins of Near Eastern food, this year's international food symposium analyzed it all

by Raymond Sokolov

I returned to the courtyard of Saint Antony's College for the 12th Oxford Food Symposium with the cozy feelings one gets from going back home. This conclave of scholars, cooks, restaurateurs, and just *fins becs*, gathering under the banner of food history, had long provided me with a sense of community and fellowship, and I was looking forward to the renewal of friendships after a two-year gap. In particular, I was glad to see Alan Davidson, a founder of the symposium, in full regalia after a serious coronary episode. This distinguished gastrotaxonomist of fish was at Saint Antony's not only to preside over two days of lectures and discussions revolving around the general topic of public eating; he was also in proud possession of his latest book.

Fruit: A Connoisseur's Guide and Cookbook is in the same gorgeous format as Davidson's earlier *Seafood*, with Charlotte Knox's stunning paintings standing opposite Davidson's meticulously precise little essays. The rigor he previously applied to fish he now has lavished on the identification and chronicling of fruits, from the homely apple to the onomatopoeic *chupa-chupa*.

The correct identification of foodstuffs, even relatively common ones, is not at all a simple business, given the immense variety of things we eat and their continuing evolution in the hands of human producers. In Oxford, I myself misidentified the main constituent of a dish at the buffet lunch on the first day of the symposium.

As usual, British attendees had each provided what we used to call covered dishes back in the Midwest. Tables were arrayed with homemade examples of far-flung human culinary ingenuity, many of

them containing strange ingredients. So I did not sense anything amiss when I took a slice of something labeled in a Spencerian hand as *pâté de pie*.

It was delicious, and I did not hesitate to compliment its maker, Alice Wooledge Salmon, on her magpie *pâté*. I had never eaten magpie before, I said. Thrush, yes—in 1970, in a juniper-flavored black *pâté de grives* at Restaurant Troisgros in Roanne, France—but never magpie.

Salmon seemed not to understand. I repeated myself. At this point, Alicia Rios from Madrid intervened, having overheard us, and asked what a magpie was. Salmon and I described the collecting, hoarding habits of *Pica pica*, the eponymous thieving magpie of Rossini's comic opera *La Gazza Ladra*. Rios nodded and said that in Spanish it was called *urraca*, but that she had never eaten one. Was there any of the *pâté* left?

Nothing but the label remained. I had misread *foie* for *pie*, so it was only a liver *pâté* after all, if a very fine one.

I was embarrassed but took comfort when even Davidson found himself at a taxonomic loss that evening, at a dinner with a Scottish theme. He was unable to identify a marine decapod somewhat like a langoustine but not quite.

"Not quite" is what a practical gastro-taxonomist says when he is about to spring into action. I am certain that Davidson is even now flipping pages in his shellfish sources, and it will not surprise me if he contributes a learned note on the matter, with animadversions on related sublobsters, in *Petits Propos Culinaires*, the periodical he edits with such flair.

It will be a concrete, if unanticipated, result of this symposium's agenda, since

the question of the shellfish's identity arose as a direct consequence of public dining (as did my own risible encounter with the "magpie" *pâté*). For the most part, however, the symposium unfolded in a series of planned sessions in which papers on public eating were delivered and discussed.

This very broad subject takes in both formal dining out, at restaurants and banquets, as well as street food. The proceedings began with a brief history of the restaurant in France by Paul Levy of *The Observer*, who had in fact discovered the actual location of the first Parisian restaurant, with some of its décor intact.

The group then split up into smaller working sessions and explored a bewildering diversity of special topics. Two papers worked up the evidence on dining out in ancient Greece and Rome. Charles Perry produced texts about food in the souks of ninth-century Baghdad. This was the Middle East before the arrival of the Turks made its food like the food we know today from the region. Perry's documents show that the principal dishes, *judhabah* and *lauzinaj*, do not resemble the shish kebab and *baklava* we would find today in Baghdad. Instead, *judhabah* was meat baked in a clay oven (like the tandoor of India) and then chopped fine, but the key feature of the dish was the sweet pudding cooked under the meat and used to catch its drippings. *Lauzinaj*, Perry showed, is the ancestor of Near Eastern shredded wheat pastries, with a filling of almond paste. Given the relative antiquity of the Near Eastern cuisine we know today, this re-creation of truly ancient souk food from before the Turks was a remarkable picture of a buried culture whose influence per-



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sists from Istanbul to Delhi, like a faded subtext in a palimpsest.

Similarly, the food of the Aztecs maintains an occult presence in modern Mexican food. Sophie Coe analyzed accounts of two great banquets of the sixteenth century: one, a feast prepared in 1520 for Montezuma, the Aztec emperor, as he stood on the threshold of catastrophe; the other, an opulent celebration among the occupying Spanish conquerors.

Doreen Fernandez, an emissary from another former Spanish colony, barely managed to get out of Manila, because yet another eruption of Mount Pinatubo closed the airport. She did make it on time, however, and discoursed on the amazingly diverse street food of the Philippines, showing how such oddments as embryo ducks and cheese ice cream fit into the very relaxed and communal life of her country.

Judith Kirkendall performed a parallel task for the street food of Hawaii's multicultural society, introducing most symposi-

asts for the first time to a concoction known as loco moco, which was "invented" in 1949 by the proprietors of the Lincoln Grill in Hilo as an after-school snack. It consists of a scoop or two of steamed white rice topped by a grilled hamburger patty, then a fried egg is added and the whole covered with a generous dollop of thick meat gravy."

The hamburger is, of course, the public food par excellence and, as such, was discussed in several papers. The worldwide popularity of fast food offered several occasions for genteel xenophobia and even an angry outburst by an American expatriate fed up, as it were, with snide remarks about the cultural imperialism of McDonald's.

The popularity of American hamburger chains around the world is a complicated phenomenon, with different causes in each culture where it happens. In the Soviet Union, the reason seems clear: McDonald's promised consumers efficient, cheerful, and predictable service. And after reading Robert A. Leonard and Wendy J. Saliba's paper on "Food, Drink and Swahili Public Space," it was easy to imagine a triumph for McDonald's classless, gender-blind system of public dining in the stratified and rule-bound society of Kenya's Indian Ocean coast. Except for little children, no one eats while walking in the street. Aristocrats never eat in restaurants but do refresh themselves in a guarded way from the elevated entrance porches of their stone houses. An intricate code, deciphered by Leonard and Saliba, controls a spectrum of related nuances.

Africans, or people of African descent, played an important if mostly forgotten part in the invention of one of Philadelphia's traditional dishes, pepper pot. William Woys Weaver gathered in a wealth of evidence to show that the soup we now think of as a relatively mild tripe soup began as a fiery street food brought from the West Indies by blacks.

Philadelphia, it turns out, had a significant black population and an important regular commerce with the Caribbean even in colonial days; and pepper pot, once a diverse and thriving minicuisine built on this early link with West African traditions, is a survival of that time. Weaver also shows that the tripe we now think of as essential to the soup was probably a substitute for the turtle meat West Indians couldn't find in the north. That's why in eighteenth-century recipes that Weaver cites, the tripe in pepper pot was cooked with spinach to turn it turtle green.

Such infiltrations of the apparently sovereign and imperialist Anglo-Saxon mas-

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L. T. Kelly, Publisher

Alan Davidson's Marmalade

(Slightly adapted from *Fruit: A Connoisseur's Guide and Cookbook*, Simon and Schuster, 1991)

Mr. Davidson writes:

This began life as my grandmother's recipe, then became that of my parents (who were both marmalade-makers), and has been progressively simplified by me in an effort to minimize the time I have to spend on making 75 pounds annually. Things I have cut out are: steeping the cut fruit overnight; fiddling around with the pips in a muslin bag; preheating anything (sugar, jars, what have you); putting waxed paper discs or melted paraffin wax on top of the marmalade before sealing it.

Yet I cling to cutting by hand.

Airing my views about marmalade, and in particular the apparent foolishness of incorporating Scotch whisky in it, led to an interesting discovery. A scientist at Cambridge University wrote to point out that, while whisky might interfere with the true flavor of marmalade, anyone who dispenses with the interior seal would do well to float a teaspoon of alcohol (which could be brandy or vodka) on top of it before applying the outer seal. This will stop mold from forming at the interface between the marmalade and the small amount of air trapped above it.

Seville oranges (bitter or bigarade oranges, sold in U. S. Hispanic markets as naranjas agrias)

1 lemon

Sugar (for amount, see below)

1. Wash the oranges and the lemon. Remove the little rosettes at the stem end and clean out any foreign matter. Chop

the fruits (unpeeled) by hand or machine, but not too finely.

2. Put chopped fruit (including peel) in a large pan with water to cover and to spare (see note). Bring to a boil and cook, uncovered, for 20 to 30 minutes or until reduced by a third.
3. Measure the result and return to heat. For every 575 milliliters (if your measuring cup isn't graduated metrically—most glass ones are today—then figure that 2½ U. S. cups is the closest practical equivalent), add 1 pound sugar, gradually, stirring until dissolved. Return to boil and continue cooking until a small amount of the mixture sets readily in a room-temperature saucer or until a candy thermometer reads 222° F. Remove from heat immediately and let stand for 5 to 10 minutes.
4. Stir, then ladle into clean jars. Fill them very nearly full. Insure that the top surface is level—no chunks of peel sticking up. Float a little alcohol, such as brandy, over the top if you wish.
5. Seal by whatever means you prefer—I just use screw-top jars and screw the tops on tight once the marmalade has cooled to just warm.

Note: As Davidson points out, the precise quantity of water is not crucial, since the final boiling of the marmalade will reduce the mixture to the correct balance of water and sugar, the sign of this being either a temperature reading of 222° F or the capacity of the mixture to set.

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ter cuisine by lustier foods and dishes from exotic places continue today. The interloping foods have usually been brought to new places by expatriates who grew up eating them. But in Australia, according to the Sydney journalist who calls herself Cherry Ripe after a popular local confection, Asian dishes and ingredients are the rage in mainstream restaurants. Non-white Asians have not immigrated to Australia in major numbers, and in any case they are not the main source of this Asian food vogue. "I would contend," Ripe writes, "that this acceptance of Asian flavors as 'every day' is due in large part to overseas travel by the peripatetic post-war baby-boom generation. . . . Such travel exposed Australians to Asian foods other than Chinese, and developed a culinary literacy which was not discarded on the return home."

Before my own return home, I took a final stroll in the courtyard of Saint Antony's and noticed a large tree laden

with fruit, little buff spheres apparently splitting open at the bud end. They were medlars, those ancient European fruits now mostly forgotten because they can't be eaten out of hand even when they're fully ripe. Only after they've been left to soften, to blet, do they acquire the rich taste and soft texture I once enjoyed long ago from fruit off a tree in Jane Grigson's Wiltshire garden. Grigson, another symposium friend, is gone now, but with her in mind, I pocketed four of the Saint Antony's medlars and sneaked them past U. S. customs. They are bletting now in my kitchen, and I aim to plant their seeds. Years from now, perhaps there will be descendants of that Saint Antony's tree in New York State, bearing fruit that I will eat with friends, a link with last fall's symposium in substance and in spirit.

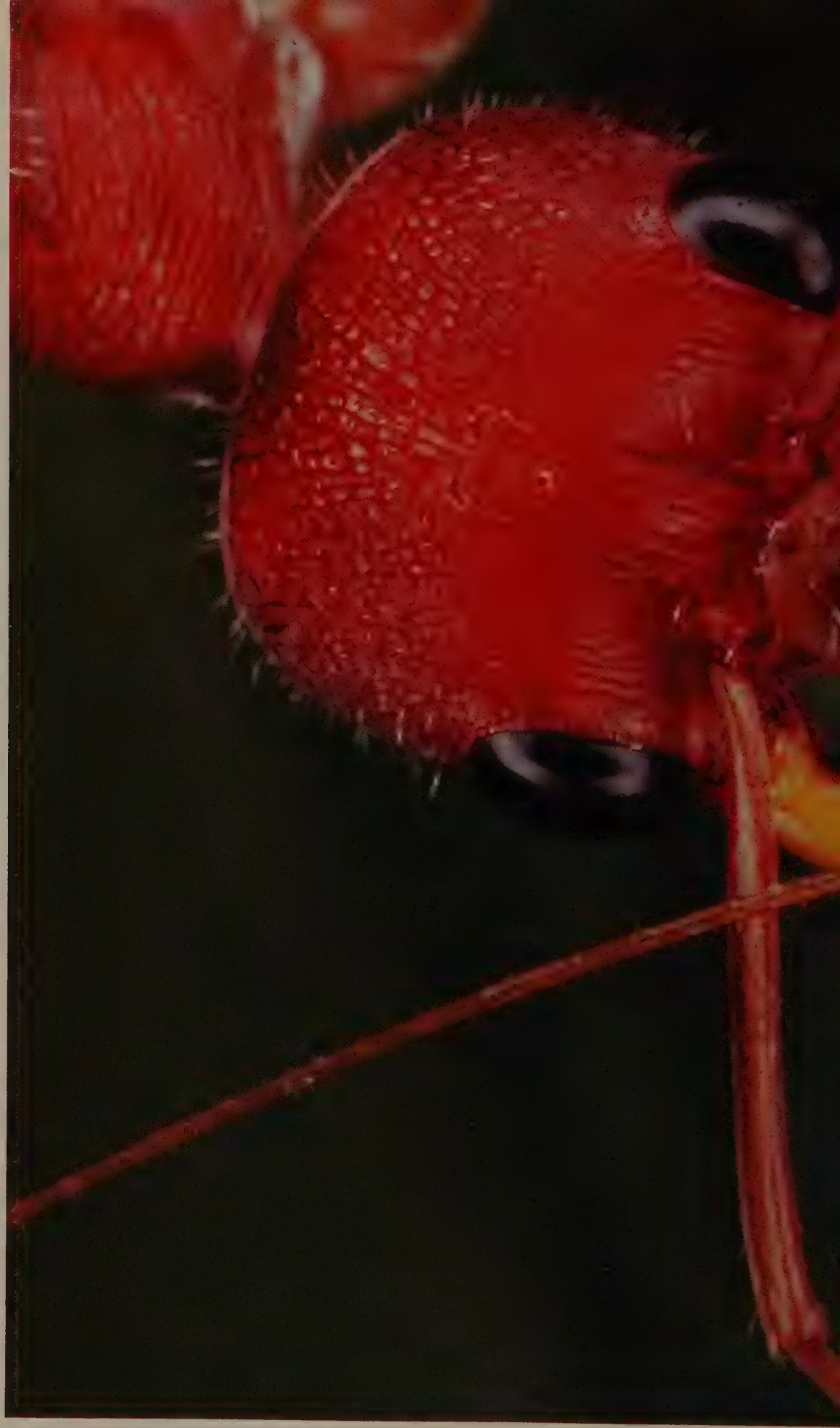
Raymond Sokolov is a writer whose special interests are the history and preparation of food.

Head for Home

The Australian bulldog ant is a fierce and solitary hunter, waylaying insects in the low-lying vegetation of the Australian bush. This female worker (top) has decapitated a katydid and is hauling the severed head home to feed the larvae in the nest. She hunts to feed the carnivorous young but prefers to dine on plant nectar herself.

Slender and about an inch long, bulldog ants, among the first types of ants to evolve, share many of the traits of their more social cousins.

They live in nests where queens lay eggs and workers tend the young and forage for food. But while most ants alert nestmates to food they have found, the bulldog ant works alone. She lies in wait, leaps upon her victim, grabs it with her mandibles, and plunges



her poisonous stinger in deep. She then tears her prey into edible pieces for the larvae to devour. The larvae of more highly evolved ants must be fed predigested meals.

Most ants are so specialized that each caste is helpless without the others, but not so among the bulldogs. Even their queen—a specialized egg layer like any other queen—can turn into a stealthy and savage hunter if that's what it takes to survive.—*Laura S. Carter*

Photograph by
David P. Maitland



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AUTHORS

An associate curator of vertebrate paleontology at the American Museum, **Mark Norell** (page 36) has seen his and his colleagues' lunchtime sketches of a *Barosaurus* in action materialize into the monumental reconstruction now in the Museum's Theodore Roosevelt Memorial Hall. Norell, who earned his doctorate in zoology from Yale in 1988, is a reptile specialist. His main interests are the comparative anatomy of recent and fossil crocodiles and the reptile fauna of Mongolia. To study the latter, he spent the last two summers on Museum expeditions to the Gobi Desert. He has also done fieldwork in West Africa, the Chilean Andes, and Cuba. Norell's interest



Peter Dodson (page 30), who never outgrew his childhood interest in dinosaurs, earned his doctorate in geology from Yale University in 1974. Since then, he has taught at the University of Pennsylvania and is now an associate professor in the departments of geology and of animal biology at the School of Veterinary Medicine. He is also a research associate at the Academy of Natural Sciences in Philadelphia. Dodson has done fieldwork in some of the richest bone beds in North America, including fossil sites in Wyoming, Montana, and southern Alberta. He is currently using

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in things old encompasses more than fossils—in his spare time he collects antiques. For further reading he suggests *Bones for Barnum Brown: Adventures of a Dinosaur Hunter*, by Roland T. Bird, edited by V. Theodore Schreiber (Fort Worth: Texas Christian University Press, 1985), which gives an account of the excavation at Howe Quarry that produced the juvenile *Barosaurus* on display at the American Museum, and *Dinosaurs Past and Present*, vols. 1 and 2, edited by Sylvia J. Czerkas and Everett C. Olson (Los Angeles: Natural History Museum of Los Angeles County in association with University of Washington Press, 1987).




computer technology to study the varied skull "architecture" of the horned dinosaurs but retains an interest in sauropods: "to understand sauropod biology is to understand the problems of the biology of size." A resident of Philadelphia, Dodson, who is active in community affairs, finds that "life in a large city is not only possible but enjoyable." He recommends David Norman's *The Illustrated Encyclopedia of Dinosaurs* (New York: Crescent Books, 1985) and Dale Russell's *An Odyssey in Time: The Dinosaurs of North America* (Toronto: University of Toronto Press, 1989).

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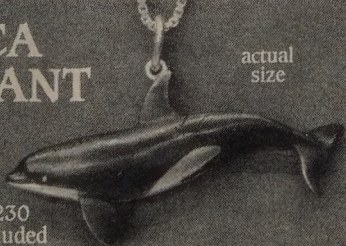
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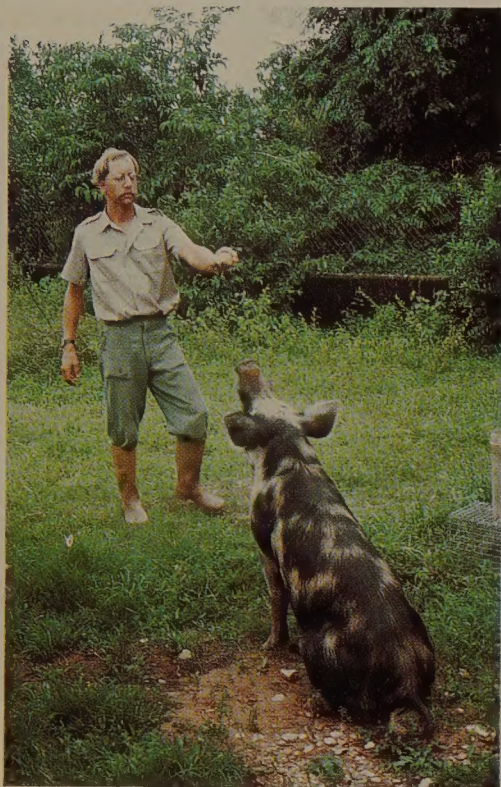
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Steven N. Austad (page 44) trains a Venezuelan pig in his spare time—an avocation he acquired after receiving a degree in English literature from the University of California, Los Angeles. His karate instructor had two pet lions, and when a movie director wanted to use them in a film, Austad, below, was enlisted to help handle the cats. From this

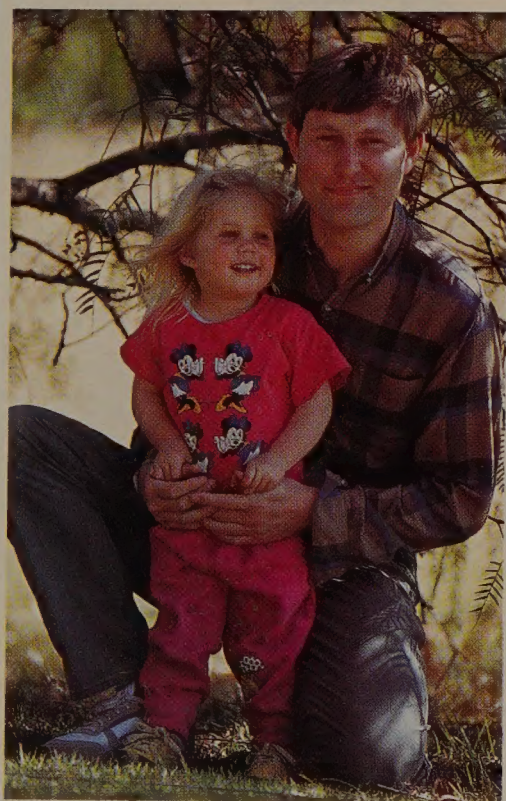
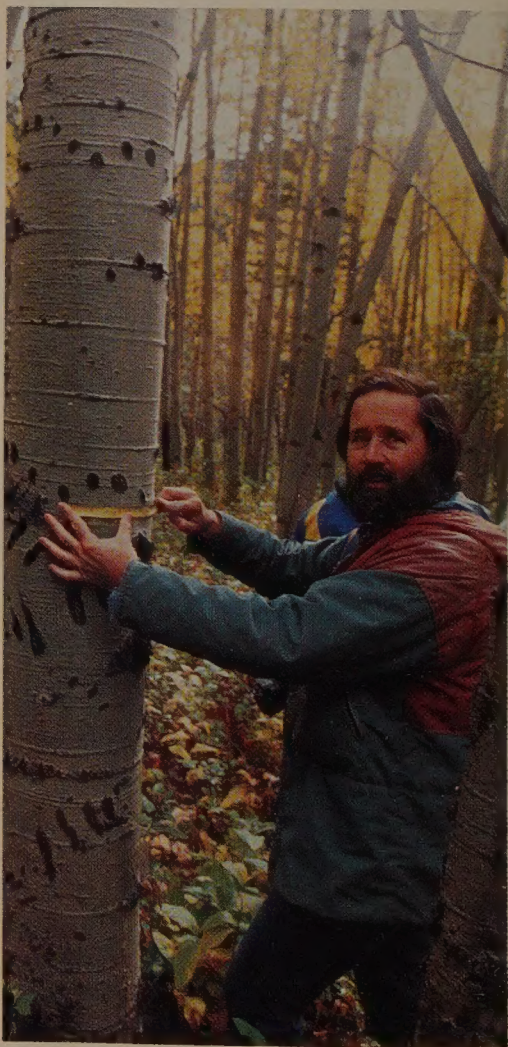


start, Austad spent three years in Hollywood training lions, tigers, and other large animals for the movie industry. This prompted him to return to school to study biology, and he earned his Ph.D. from Purdue University in 1981. Austad is now an associate professor at Harvard



in the Department of Organismic and Evolutionary Biology. His interest in European nursery web spiders goes back to research for his Ph.D. He teamed up with **Randy Thornhill**, above, to study the spiders because of Thornhill's extensive knowledge of similar nuptial gift giving in insects. Thornhill received his Ph.D. from the University of Michigan and has devoted most of his career to studying insect mating behavior. He is currently a professor of biology at the University of New Mexico and has recently traveled to Japan to pursue his interest in scorpion flies. Like Austad, Thornhill's interests range from arthropods to large mammals. For further reading on the mating habits of spiders, the authors recommend Rainer Foelix's book *Biology of Spiders* (Cambridge: Harvard University Press, 1982).

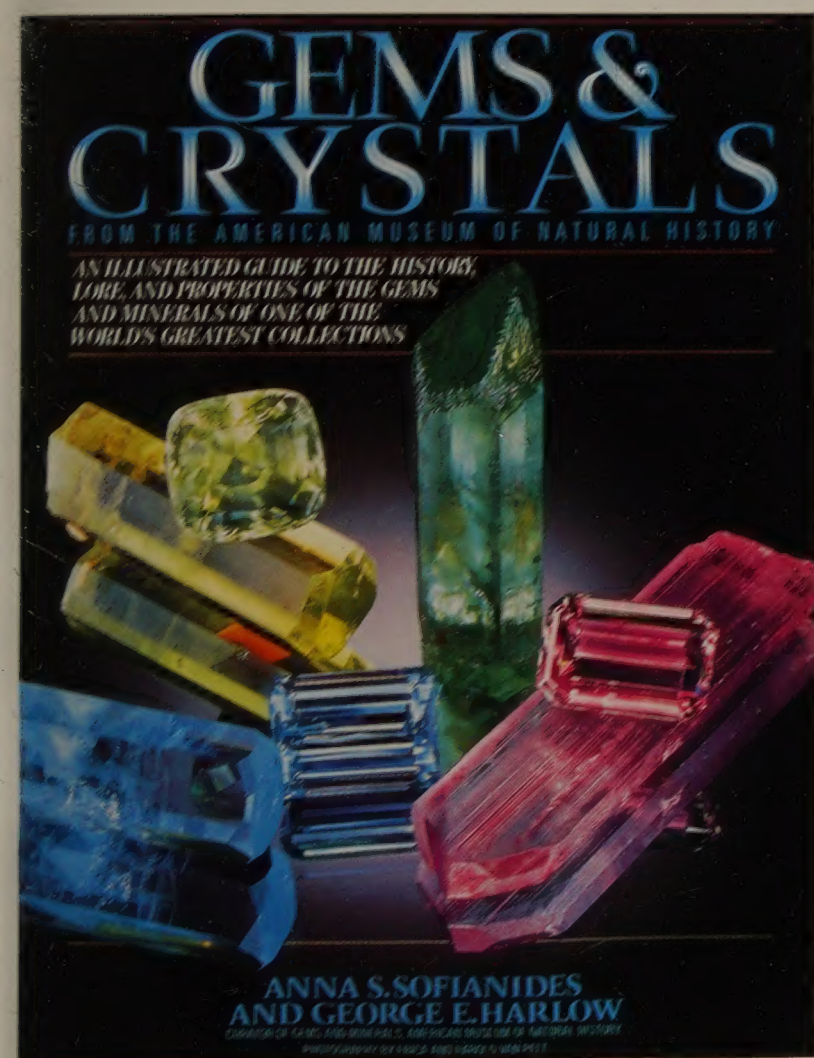
James C. Halfpenny's two great loves are winter ecology and tracking, which fortunately can be readily combined in the Yellowstone area, where he has spent the last twenty winters. A research associate at both the University of Colorado Museum and the Institute of Arctic and Alpine Research in Boulder, Halfpenny (page 50) also teaches winter ecology at the Teton Science School in Kelly, Wyoming. He uses his tracking skills to study endangered mammals during the winter. Much of his work has been on wolverines, lions, and Canada lynxes, in an effort to determine their status, often in as yet undisturbed areas. Tracking has also taken him to Tanzania and the Tibetan-Qinghai plateau. Currently, he is doing a comparative tracking study of North America's three species of bears. Halfpenny is author of *A Field Guide to Mammal Tracking in North America* (Boulder: Johnson Books, 1987) and, together with Roy Douglas Ozanne, of *Winter: An Ecological Handbook* (Boulder: Johnson Books, 1989). Other books about winter include the just published second edition of Peter Marchand's nicely written *Life in the Cold: An Introduction to Winter Ecology* (Hanover: University Press of New England, 1991) and Donald W. Stokes's *A Guide to Nature in Winter* (Boston: Little, Brown and Co., 1976).



David P. Maitland (page 80) ran into the Australian bulldog ant in 1983, when he started fieldwork in Australia for his Ph.D. "After my first painful encounter with such a large, formidable ant (their sting is worse than their bite), I had in mind to take a portrait along the lines of the one featured. But I had to wait four years before I found myself in the right place at the right time. Photographing them can be dangerous, as they crawl up your trouser leg while you're trying to concentrate on a subject." Maitland, pictured here with his daughter, Laura, is an associate professor of physiology at the Medical School of the University of Witwatersrand in South Africa. When he's in the field, studying air breathing in crabs, he takes close-ups of insects and other small creatures. He photographed this ferocious ant using an Olympus OM4 camera with a 38mm lens on extension tubes and a ring flash.

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